Guide to the Geology of the Beardstown Area, Cass, Schuyler, and Brown Counties, Illinois

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Field Trip Guidebook 1996A April 13, 1996

Department of Natural Resources
ILLINOIS STATE GEOLOGICAL SURVEY

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Natural Resources Building
William W. Shilts, Chief
615 E. Peabody Drive
Champaign, IL 61820

Cover photo Slump along Panther Creek, south of confluence with Cox Creek (photo by Bob Sinclair).

Geological Science Field Trips The Educational Extension Unit of the Illinois State Geological Survey (ISGS) conducts four tours each year to acquaint the public with the rocks, mineral resources, and landscapes of various regions of the state and the geological processes that have led to their origin. Each trip is an all-day excursion through one or more Illinois counties. Frequent stops are made to explore interesting phenomena, explain the processes that shape our environment, discuss principles of earth science, and collect rocks and fossils. People of all ages and interests are welcome. The trips are especially helpful to teachers who prepare earth science units. Grade school students are welcome, but each must be accompanied by a parent or guardian. High school science classes should be supervised by at least one adult for each ten students.

A list of guidebooks of earlier field trips for planning class tours and private outings may be obtained by contacting the Educational Extension Unit, Illinois State Geological Survey, Natural Resources Building, 615 East Peabody Drive, Champaign, IL 61820. Telephone: (217) 244-2427 or 333-4747.

Twelve USGS 7.5-minute topographic quadrangle maps (all available from the ISGS) provide coverage for the field trip: Arenzville East, Arenzville West, Ashland, Beardstown, Clear Lake, Chandlerville, Cooperstown, Newmansville, Ripley, Rushville South, Versailles, and Virginia.

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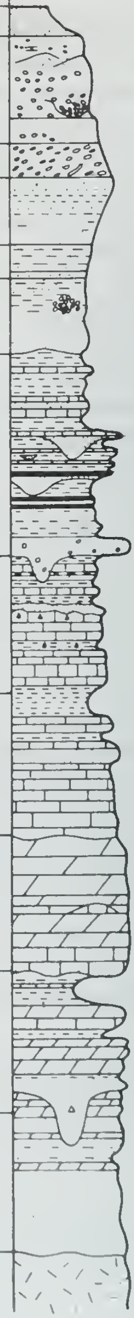
CONTENTS

Era		Period or System and Thickness	Epoch	Age (years ago)	General Types of Rocks
CENOZOIC "Recent Life"	Age of Mammals	Quaternary 0–500'	Holocene	10,000	Recent—alluvium in river valleys
			Pleistocene Glacial Age	1.6 m.	Glacial till, glacial outwash, gravel, sand, silt, lake deposits of clay and silt, loess and sand dunes; covers nearly all of state except northwest corner and southern tip
		Tertiary 0–500'	Pliocene	5.3 m.	Chert gravel, present in northern, southern, and western Illinois
				36.6 m.	
			Eocene	57.8 m.	Mostly micaceous sand with some silt and clay; present only in southern Illinois
			Paleocene	66.4 m.	Mostly clay, little sand; present only in southern Illinois
MESOZOIC "Middle Life"	Age of Reptiles	Cretaceous 0–300'		144 m.	Mostly sand, some thin beds of clay and, locally, gravel; present only in southern Illinois
				286 m.	
PALEOZOIC "Ancient Life"	Age of Amphibians and Early Plants	Pennsylvanian 0–3,000' ("Coal Measures")		320 m.	Largely shale and sandstone with beds of coal, limestone, and clay
		Mississippian 0–3,500'		360 m.	Black and gray shale at base; middle zone of thick limestone that grades to siltstone, chert, and shale; upper zone of interbedded sandstone, shale, and limestone
	Age of Fishes	Devonian 0–1,500'		408 m.	Thick limestone, minor sandstones and shales; largely chert and cherty limestone in southern Illinois; black shale at top
	Age of Invertebrates	Silurian 0–1,000'		438 m.	Principally dolomite and limestone
		Ordovician 500–2,000'		505 m.	Largely dolomite and limestone but contains sandstone, shale, and siltstone formations
		Cambrian 1,500–3,000'		570 m.	Chiefly sandstones with some dolomite and shale, exposed only in small areas in north-central Illinois
		Precambrian			Igneous and metamorphic rocks, known in Illinois only from deep wells



Generalized geologic column showing succession of rocks in Illinois.

BEARDSTOWN AREA

The Beardstown geological science field trip will acquaint you with the *geology* *, landscape, and mineral resources of parts of Cass, Schuyler, and Brown Counties, Illinois. The city of Beardstown is located in west-central Illinois along the Illinois River, approximately 200 miles southwest of Chicago, 50 miles northwest of Springfield, 100 miles north of St. Louis, and 230 miles northwest of Cairo.

GEOLOGIC FRAMEWORK

Precambrian Era Through the several billion years of geologic time, Cass, Schuyler, and Brown Counties and surrounding areas have undergone many changes (see the generalized geologic column, facing page). The oldest rocks beneath the field trip area belong to the ancient Precambrian *basement complex*. We know relatively little about these rocks from direct observations because they are not exposed at the surface anywhere in Illinois. Only about 35 drill holes have reached deep enough for geologists to collect samples from the Precambrian rocks of Illinois. From these samples, however, we know that these ancient rocks consist mostly of granitic and rhyolitic *igneous*, and possibly *metamorphic*, crystalline rocks formed about 1.5 to 1 billion years ago. From about 1 billion to about 0.6 billion years ago, these Precambrian rocks were exposed at the surface. During this long period, the rocks were deeply weathered and eroded, and formed a landscape that was probably quite similar to that of the present Missouri Ozarks. We have no rock record in Illinois for the long interval of *weathering* and erosion that lasted from the time the Precambrian rocks were formed until the first Cambrian-aged *sediments* accumulated, but that interval is almost as long as the time from the beginning of the Cambrian Period to the present.

Because geologists cannot see the Precambrian basement rocks in Illinois except as cuttings and cores from drillholes, they must use various other techniques, such as measurements of Earth's gravitational and magnetic fields and seismic exploration, to map out the regional characteristics of the basement complex. The evidence indicates that in southernmost Illinois, near what is now the historic Kentucky–Illinois Fluorspar Mining District, rift valleys like those in east Africa formed as movements of crustal plates (plate *tectonics*) began to rip apart the Precambrian-age North American continent. These rift valleys in the midcontinent region are referred to as the Rough Creek Graben and the Reelfoot Rift (fig. 1).

Paleozoic Era After the beginning of the Paleozoic Era, about 520 million years ago in the late Cambrian Period, the rifting stopped and the hilly Precambrian landscape began to sink slowly on a broad regional scale, allowing the invasion of a shallow sea from the south and southwest. During the several hundred million years of the Paleozoic Era, the area that is now southern Illinois continued to accumulate sediments deposited in the shallow seas that repeatedly covered it. The region continued to sink until at least 15,000 feet of sedimentary strata was deposited. At times during this era the seas withdrew and deposits were weathered and eroded. As a result, there are some gaps in the sedimentary record in Illinois.

In the field trip area, *bedrock* strata range from more than 520 million years (the Cambrian *Period*) to less than 290 million years old (the Pennsylvanian Period). Figure 2 shows the succession of rock strata a drill bit would penetrate in this area if the rock record were complete and all the *formations* were present.

The elevation of the top of the Precambrian basement rocks within the field trip area ranges from less than 3,000 feet below sea level in eastern Schuyler and Brown Counties to more than 4,000 feet below sea level in eastern Cass County. This 1,000 foot difference in elevation takes place within

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*Words in italics are defined in the glossary at the back of the guidebook. Also please note: although all present localities have only recently appeared within the geologic time frame, we use the present names of places and geologic features because they provide clear reference points for describing the ancient landscape.

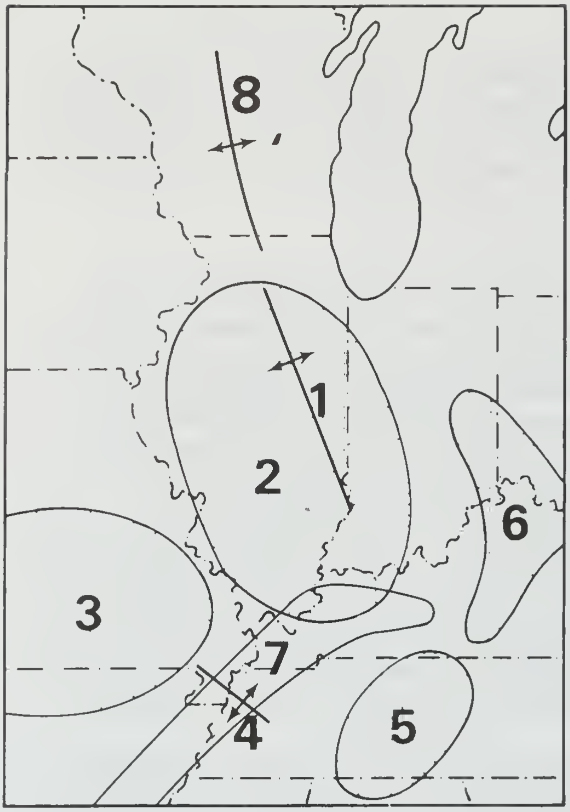


Figure 1 Location of some of the major structures in the Illinois region. (1) La Salle Anticlinorium, (2) Illinois Basin, (3) Ozark Dome, (4) Pascola Arch, (5) Nashville Dome, (6) Cincinnati Arch, (7) Rough Creek Graben-Reelfoot Rift, and (8) Wisconsin Arch.

a distance of approximately 30 miles. The top surface of the Precambrian rocks dips eastward into the Illinois Basin at a rate of approximately 33 feet per mile. The thickness of the Paleozoic sedimentary strata ranges from about 3,700 feet in eastern Schuyler and Brown Counties to about 4,600 feet in eastern Cass County.

Pennsylvanian-age bedrock strata consisting of shale, siltstone, sandstone, limestone, coal, and underclay were deposited as sediments in shallow seas and swamps between about 320 and 286 million years ago. In general, within the field trip area, these rocks are found at the surface or immediately beneath a thin cover of glacial deposits west of the Illinois River in eastern Schuyler and Brown Counties, and beneath a thick cover of glacial deposits east of the Illinois River in Cass County. Rocks of Pennsylvanian age are exposed in roadcuts and along the ravines and stream valleys that have been eroded into the bluffs on the west side of the Illinois River.

Pennsylvanian strata within the field trip area increase in thickness from 0 feet along the Illinois and La Moine Rivers, where they have been completely removed by erosion, to approximately 300 feet in eastern Cass County. An erosional unconformity between the overlying glacial deposits of the Quaternary Period and the Pennsylvanian deposits within the field trip area provides evidence that some of the Pennsylvanian rocks were removed by erosion. Thickness of Pennsylvanian strata increases to 2,500 feet in southern Illinois. (See *Depositional History of the Pennsylvanian Rocks* in the supplemental reading at the back of this guidebook for a more complete description of these rocks.)

Mississippian-age bedrock strata are found immediately beneath the Pennsylvanian rocks or directly under the glacial deposits where the Pennsylvanian rocks have been eroded away. Mississippian strata outcrop in eastern Schuyler and Brown Counties, but are not exposed east of the Illinois River within the field trip area. The Mississippian rocks exposed within the field trip area include the St. Louis, Salem, and Warsaw Formations, which consist of limestones, dolomites,

SYSTEM	SERIES	GROUP	FORMATION	GRAPHIC COLUMN	THICKNESS (FEET)	LITHOLOGY
QUATERNARY	PLEISTOCENE				0-100+	Loess, till, sand, gravel, silt
TERTIARY	PLIOCENE				0-10	Gravel
PENNSYLVANIAN		McLeansboro				
					500	Shale, sandstone, clay, coal, limestone
		Racoon Crk				
MISSISSIPPIAN	VALMEYERAN	Meramecan	St. Louis		0-150	Limestone, light, cherty
			Salem		0-46	Dolomite, sandstone, and sandy shale
		Osagian	Warsaw		0-75	Shale, dolomitic, with geodes
			Keokuk		0-140	Limestone, cherty
			Burlington		80-100	Limestone, cherty
	KINDERHOOKIAN		Hannibal		75-150	Shale, greenish and gray
	UPPER		Grassy Creek		110-160	Shale, brownish gray to black
DEVONIAN	MIDDLE		Cedar Valley		0-100	Limestone, crystalline, dolomitic, sandy
			Wapsipinicon		0-35	Limestone, dolomite
SILURIAN	NIAGARAN				0-210	Dolomite, light gray, cherty
	ALEXANDRIAN		Kankakee		0-45	Dolomite, light gray
			Edgewood		15-20	Dolomite, sandy, shaly
ORDOVICIAN	CINCINNATIAN	Maquoketa			70-90	Shale, dolomitic, brown
					6-30	Dolomite, brownish gray
					50-90	Shale, dolomitic, brown to black
	CHAMPLAINIAN	Galena			175-200	Dolomite, buff, crystalline, porous
					5-20	Dolomite, shaly
		Platteville			100	Dolomite, buff, fine-grained
		Ancell	Glenwood		60-100	Sandstone, shale and dolomite, glauconitic
			St. Peter		170-250	Sandstone, light buff, incoherent
	CANADIAN	PRAIRIE DU CHIEN	Shakopee		160	Dolomite, reddish, argillaceous
			New Richmond		70	Sandstone, dolomitic
			Oneota		353	Dolomite, with oolitic chert
			Gunter		36	Dolomite, sandy
CAMBRIAN	ST. CROIXAN		Eminence		100	Dolomite, light gray, with oolitic chert
			Potosi		210	Dolomite, brown to pinkish gray, glauconitic
			Franconia		131	Dolomite, sandy, glauconitic
			Galesville		137	Sandstone, light buff, incoherent
			Eau Claire		2' penetrated	Dolomite, sandy

Figure 2 Generalized columnar section of the Beardstown area (modified from Wanless 1957).

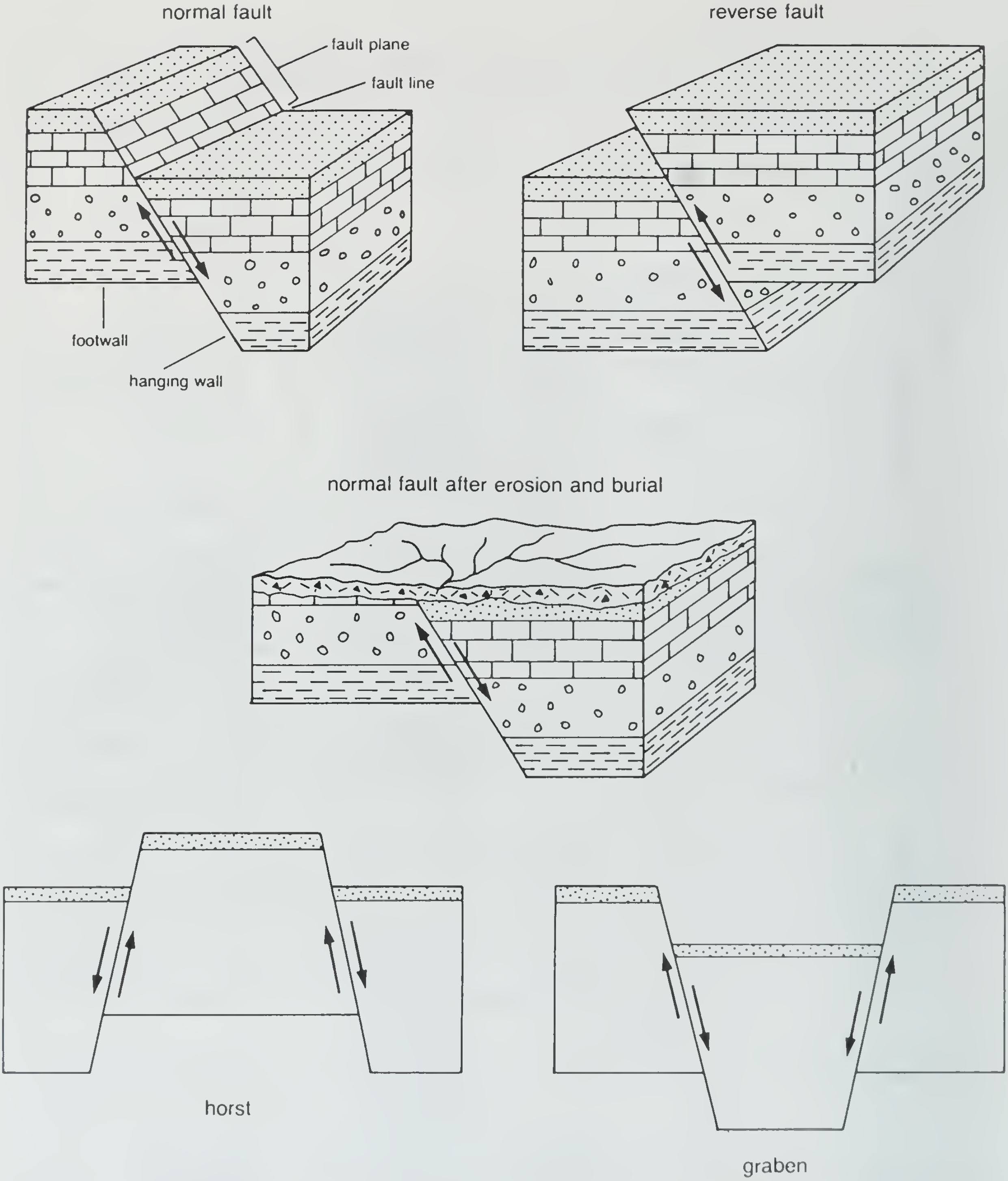


Figure 3 Diagrammatic illustrations of fault types that may be present in the field trip area. Arrows indicate relative directions of movement on each side of the fault.

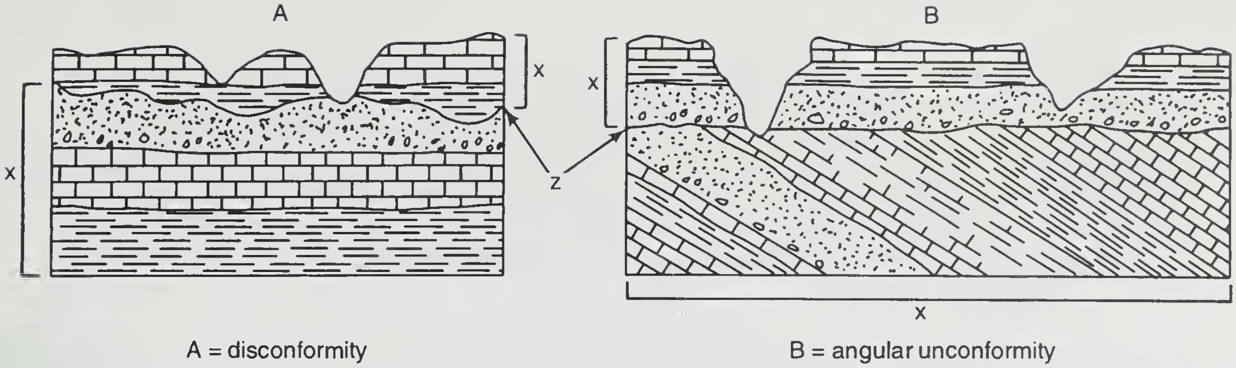


Figure 4 Schematic drawings of (A) a disconformity and (B) an angular unconformity. X represents the conformable rock sequence and z is the plane of unconformity.

shales, and sandstones. Deposited as sediments in shallow seas between 360 and 320 million years ago, these formations are part of the thick succession of strata in the upper Mississippi River Valley in Illinois that constitute the type section for rocks of the Mississippian Period throughout the world. The total thickness of Mississippian strata increases from approximately 350 feet in eastern Schuyler and Brown Counties to more than 550 feet in eastern Cass County. Mississippian rocks are as thick as 3,200 feet in southern Illinois but thin northward because of both erosion of the top surface and depositional thinning of many of the component formations. (See *Mississippian Rocks in Illinois* at the back of this guidebook for a more complete description of these rocks.)

STRUCTURAL AND DEPOSITIONAL HISTORY

As noted previously, the Rough Creek Graben and the Reelfoot Rift (figs. 1 and 3) were formed by tectonic activity that began in the latter part of the Precambrian Era and continued until the Late Cambrian. Toward the end of the Cambrian, rifting ended and the whole region began to subside, allowing shallow seas to cover the land.

Paleozoic and Mesozoic Eras From the Late Cambrian to the end of the Paleozoic Era, sediments continued to accumulate in the shallow seas that repeatedly covered Illinois and adjacent states. These inland seas connected with the open ocean to the south during much of the Paleozoic, and the area that is now southern Illinois was like an embayment. The southern part of Illinois and adjacent parts of Indiana and Kentucky sank more rapidly than areas to the north, allowing a greater thickness of sediment to accumulate. Earth's thin crust was periodically flexed and warped as stresses built up in places. These movements caused repeated invasions and withdrawals of the seas across the region. The former seafloors were thus periodically exposed to erosion, which removed some sediments from the rock record.

Many of the sedimentary units, called formations, have conformable contacts—that is, no significant interruption in deposition occurred as one formation was succeeded by another (figs. 2 and 4). In some instances, even though the composition and appearance of the rocks change significantly at the contact between two formations, the *fossils* in the rocks and the relationships between the rocks at the contact indicate that deposition was virtually continuous. In some places, however, the top of the lower formation was at least partially eroded before deposition of the next formation began. Fossils and other evidence in the two formations indicate that there is a significant age difference between the lower unit and the overlying one. This type of contact is called an *unconformity* (fig. 4). If the beds above and below an unconformity are parallel, the unconformity is called a *disconformity*; if the lower beds have been tilted by tectonic forces and eroded before the overlying beds were deposited, the contact is called an angular unconformity. Unconformities are shown in the graphic column in figure 2 as wavy lines. Each unconformity represents an interval of time for which there is no rock record.

Near the close of the Mississippian Period, gentle arching of the rocks in eastern Illinois initiated the development of the La Salle Anticlinorium (figs. 1 and 5). This is a complex structure having smaller structures such as domes, *anticlines*, and *synclines* superimposed on the broad upwarp of the anticlinorium. Further gradual arching continued through the Pennsylvanian Period. Because the youngest Pennsylvanian strata are absent from the area of the anticlinorium (either because they were not deposited or because they were eroded), we cannot determine just when folding ceased—perhaps by the end of the Pennsylvanian or during the Permian Period a little later, near the close of the Paleozoic Era.

During the Mesozoic Era, which followed the Paleozoic Era, the rise of the Pascola Arch (fig. 1) in southeastern Missouri and western Tennessee formed the Illinois *Basin* by closing off the embayment and separating it from the open sea to the south. The Illinois Basin is a broad, subsided region covering much of Illinois, southwestern Indiana, and western Kentucky (fig. 1). Development of the Pascola Arch, in conjunction with the earlier sinking of deeper parts of the area to the north, gave the basin its present asymmetrical, spoon-shaped configuration (fig. 6). The geologic map (fig. 7) shows the distribution of the rock *systems* of the various geologic time periods as they would appear if all the glacial, windblown, and surface materials were removed.

The Beardstown field trip area is located on the western shelf of the Illinois Basin (fig. 5). Structural features within the field trip area include several northeast–southwest-trending anticlines and synclines. From north to south these include: the Table Grove Syncline, the Littleton Anticline, the Astoria Anticline, the Ripley Syncline, and the Versailles Anticline (fig. 8). The Fishhook Anticline and the Colmar Anticline, structures from which oil and/or natural gas have been produced, mark the northwest and southwest corners of the field trip area.

Younger rocks of the latest Pennsylvanian and perhaps the Permian (the youngest rock system of the Paleozoic) may at one time have covered the areas of Cass, Schuyler, and Brown Counties. It is possible that Mesozoic and Cenozoic rocks (see generalized geologic column) could also have been present here. Indirect evidence, based on the stage of development (rank) of coal deposits and the generation and maturation of petroleum from source rocks (Damberger 1971), indicates that perhaps as much as 1.5 miles of latest Pennsylvanian and younger rocks once covered southern Illinois. However, during the more than 240 million years since the end of the Paleozoic Era (and before the onset of *glaciation* 1 to 2 million years ago), several thousands of feet of strata may have been eroded. Nearly all traces of any post-Pennsylvanian bedrock that may have been present in Illinois were removed. During this extended period of erosion, deep valleys were carved into the gently tilted bedrock formations (fig. 9). Later, the topographic *relief* was reduced by repeated advances and melting back of continental glaciers that scoured and scraped the bedrock surface. This glacial erosion affected all the formations exposed at the bedrock surface in Illinois. The final melting of the glaciers left behind the nonlithified deposits in which our Modern Soil has developed.

Cenozoic Era: Glacial History A brief general history of glaciation in North America and a description of the deposits commonly left by glaciers may be found in *Pleistocene Glaciations in Illinois* at the back of the guidebook.

Prior to glaciation, Cass, Schuyler, and Brown Counties and adjacent areas were drained by several ancient bedrock valleys, including the Lower Illinois, Crooked Creek, and the Arenzville valleys (fig. 9). After glaciation, new drainage systems were established. Some of these follow the same trends of the buried valleys. For example, the modern Illinois River follows the ancient Lower Illinois Bedrock valley, and the La Moine River follows the ancient course of the Crooked Creek valley. The ancient Arenzville Bedrock valley is completely covered by glacial sediments. Quaternary deposits along the Illinois and La Moine River valleys are 50 to 200 feet thick.

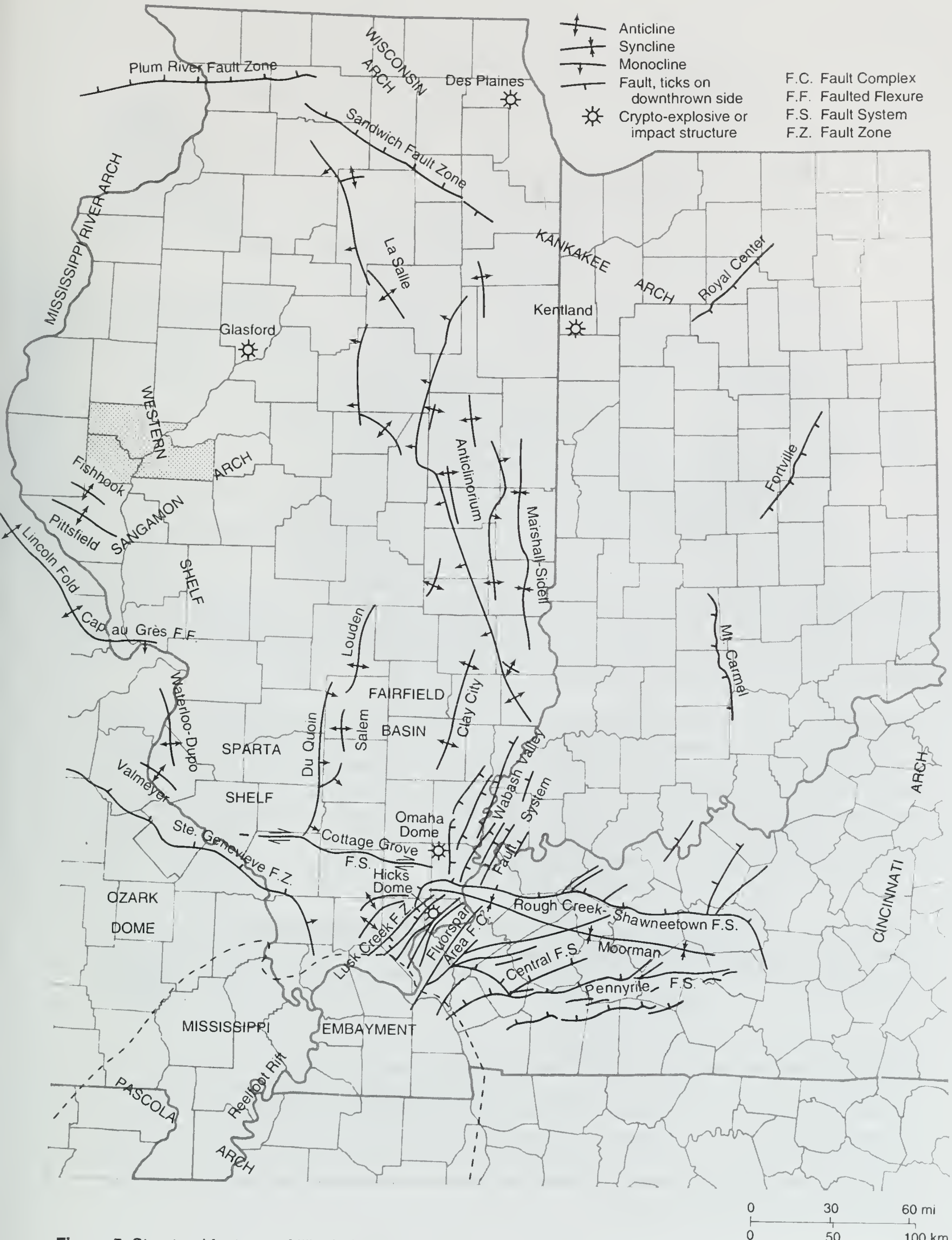


Figure 5 Structural features of Illinois (modified from Buschbach and Kolata 1991).

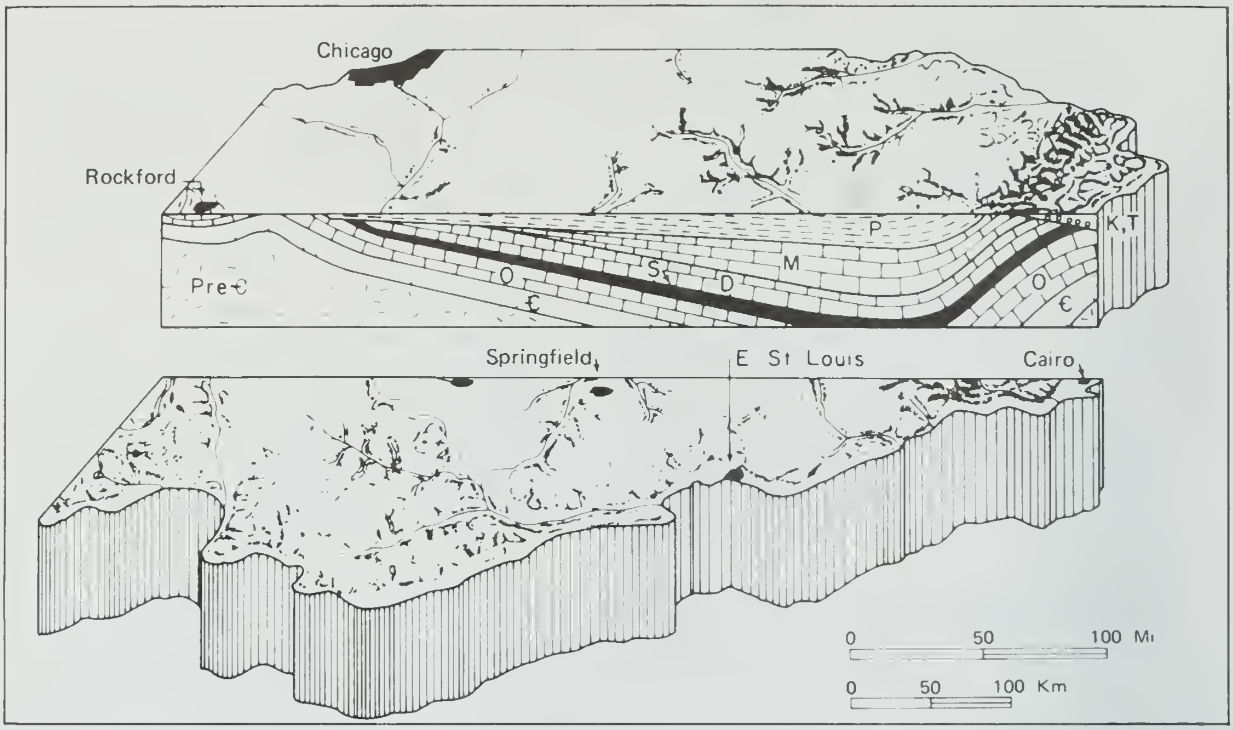


Figure 6 Stylized north–south cross section shows the structure of the Illinois Basin. To show detail, the thickness of the sedimentary rocks has been greatly exaggerated and younger, unconsolidated surface deposits have been eliminated. The oldest rocks are Precambrian (Pre-Є) granites. They form a depression filled with layers of sedimentary rocks of various ages: Cambrian (Є), Ordovician (O), Silurian (S), Devonian (D), Mississippian (M), Pennsylvanian (P), Cretaceous (K), and Tertiary (T). Scale is approximate.

During the Pleistocene *Epoch*, beginning about 1.6 million years ago, massive sheets of ice (called continental glaciers), thousands of feet thick, flowed slowly southward from Canada. The last of these glaciers melted from northeastern Illinois about 13,500 years before the present (B.P.). During the Illinoian glaciation (also now called the Illinois Episode), which began around 300,000 years B.P., North American continental glaciers reached their southernmost position approximately 175 miles southeast of Beardstown in the northern part of Johnson County (fig. 10). The maximum thickness of the later Wisconsin Episode glacier was about 2,000 feet in the Lake Michigan Basin, but only about 700 feet over most of the Illinois land surface (Clark et al. 1988).

The *topography* of the bedrock surface throughout much of Illinois is largely hidden from view by glacial deposits except along the major streams. In many areas, the glacial drift is thick enough to completely mask the underlying bedrock surface. Most of Cass, Schuyler, and Brown Counties is covered either by glacial moraines and ridged drift or by ground moraines of the Illinois glacial episode.

Although the Illinois Episode glaciers probably built glacial moraines similar to those of the later Wisconsin Episode glaciers, the Illinois Episode moraines apparently were not so numerous and have been exposed to weathering and erosion for thousands of years longer than the younger moraines of the Wisconsin Episode. For these reasons, features formed during the Illinois Episode generally are not as conspicuous as those formed during the Wisconsin Episode. However, within the field trip area, an Illinoian moraine occurs parallel to the Illinois River along the southeast edge of Schuyler County. Outside of the Illinois, Sangamon, and La Moine River Valleys, the glacial deposits consist of ground moraines.

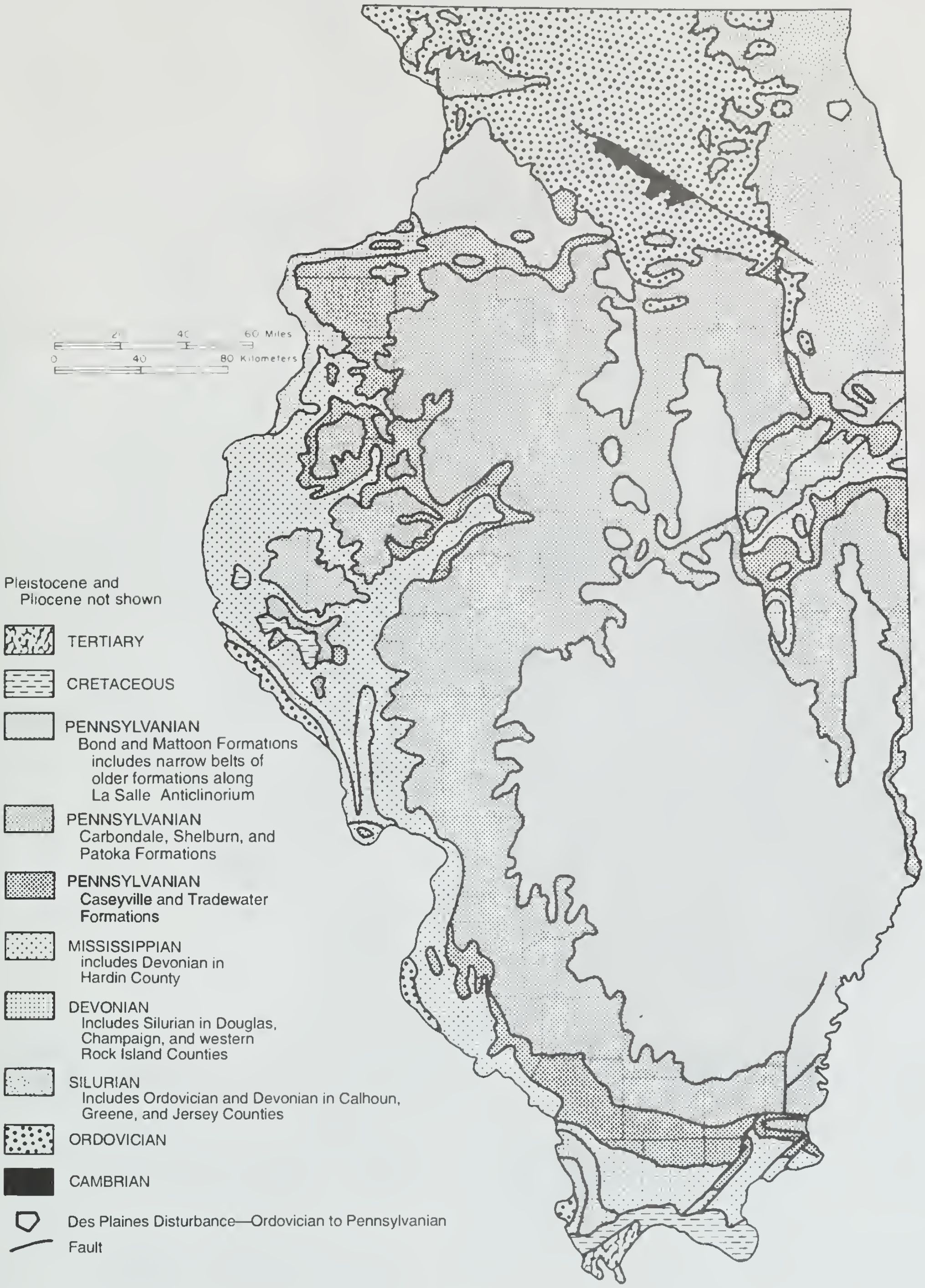


Figure 7 Bedrock geology beneath surficial deposits in Illinois.

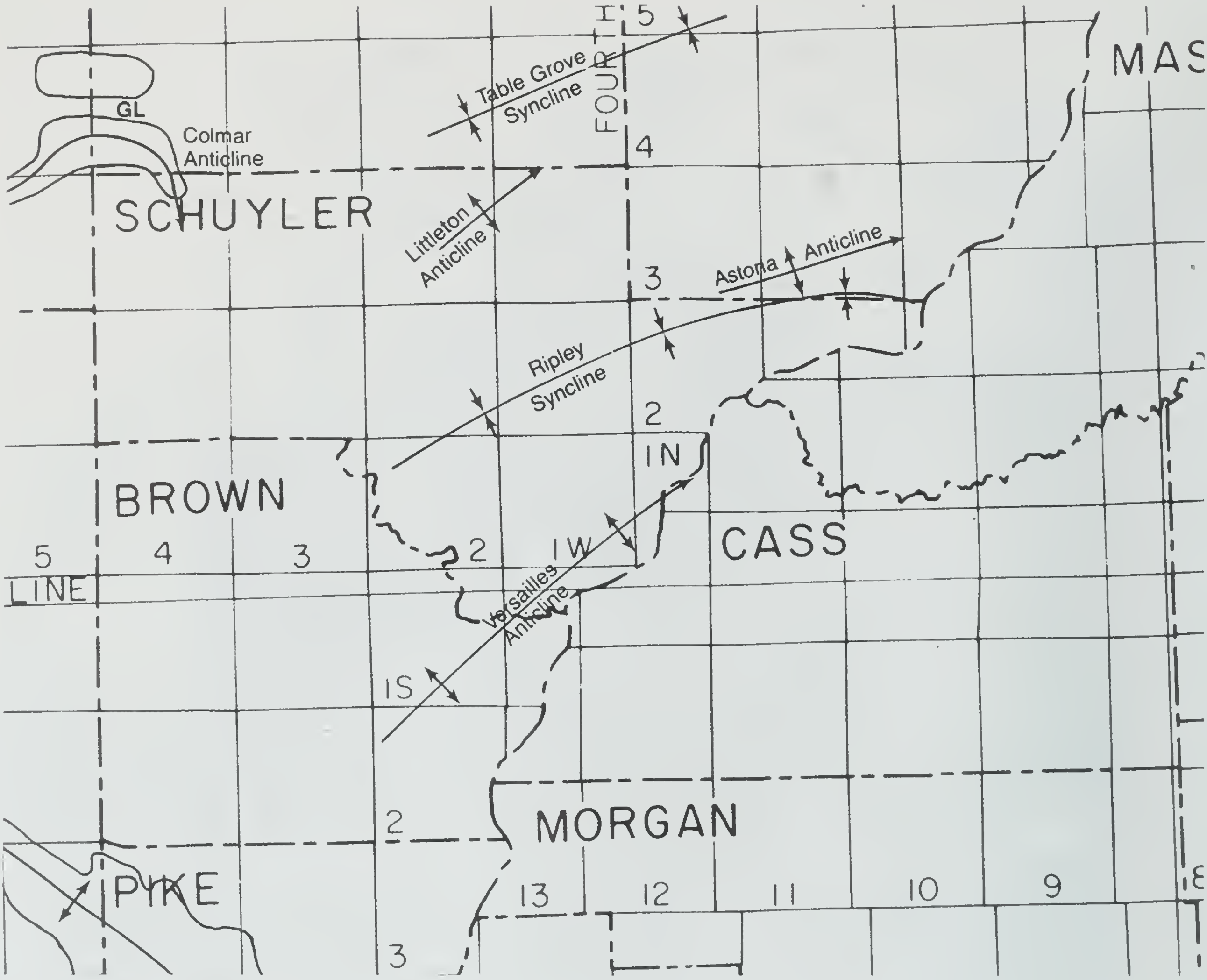


Figure 8 Structural features in the field trip area (modified from Nelson 1995).

Overlying the Illinois Episode deposits are a thick cover of Wisconsin Episode deposits called the Peoria *Loess* (pronounced luss). These sediments, deposited as windblown silts during the Woodfordian *Subage* which began about 22,000 B.P., mantle the glacial drift throughout the field trip area. (See *Pleistocene Glaciations in Illinois* at the back of the guidebook.) Thickness of the loess decreases from approximately 25 feet adjacent to the Illinois River valley to approximately 12.5 feet in central Schuyler and Brown Counties to the west and central Cass County to the east. This fine-grained dust, which covers most of Illinois, commonly reaches thicknesses exceeding 25 feet along most of the Mississippi and Illinois Rivers, and is as much as 80 feet thick on the east bluff of the Mississippi Valley in the East St. Louis area. (Loess deposits are described in *Ancient Dust Storms in Illinois - Geogram 5* at the back of the guidebook.) Soils in this area on top of the bluffs and along the bluff slopes have developed in the loess and in the underlying weathered silty, clayey Illinoian *till*.

GEOMORPHOLOGY

Physiography The Beardstown field trip area includes parts of the Galesburg Plain west of the Illinois River and the Springfield Plain east of the Illinois River; both are part of the Till Plains Section of the Central Lowland Physiographic Province (fig. 11). The Till Plains Section is in an early

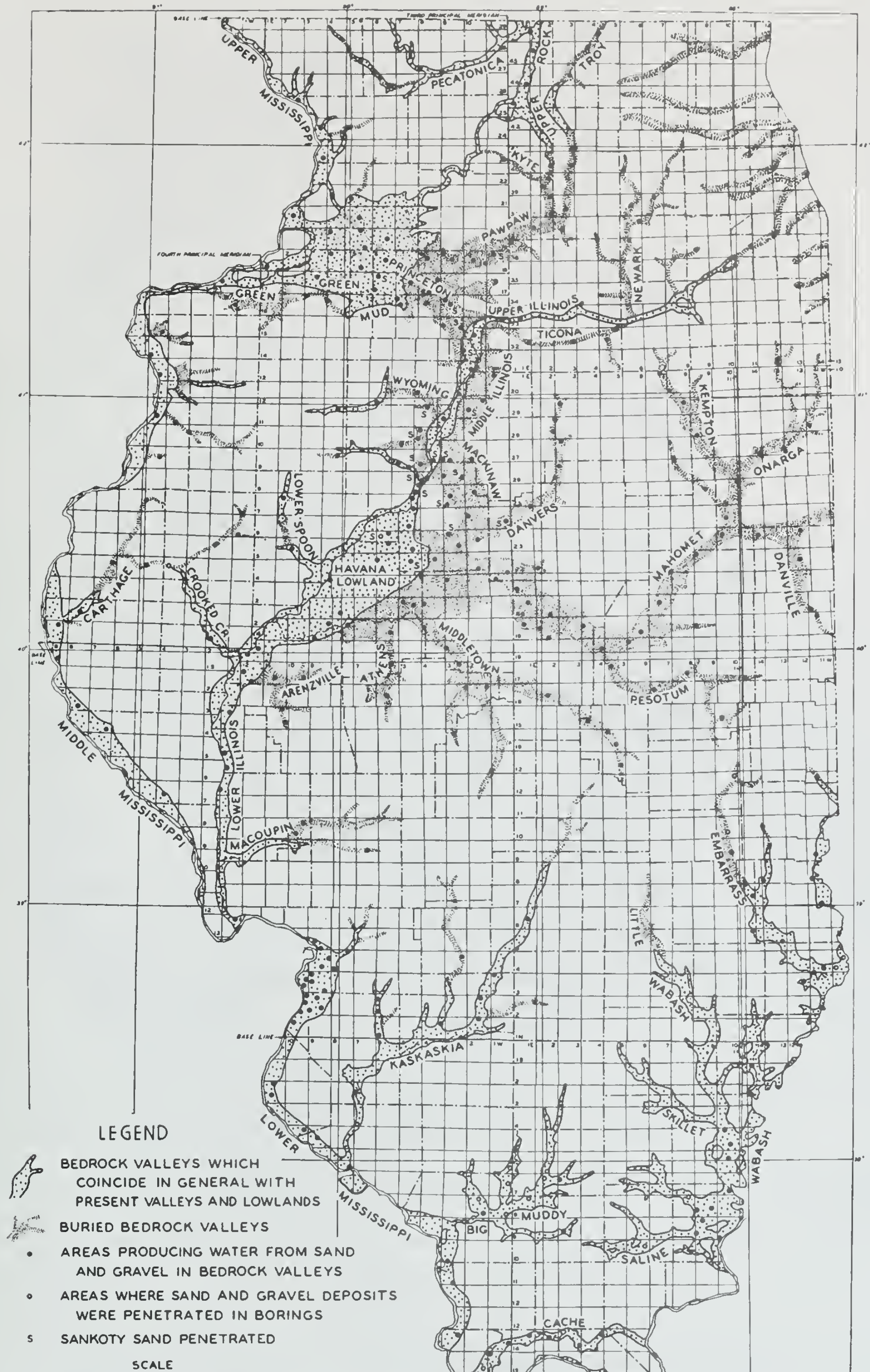


Figure 9 Bedrock valleys of Illinois (modified from Horberg 1950).

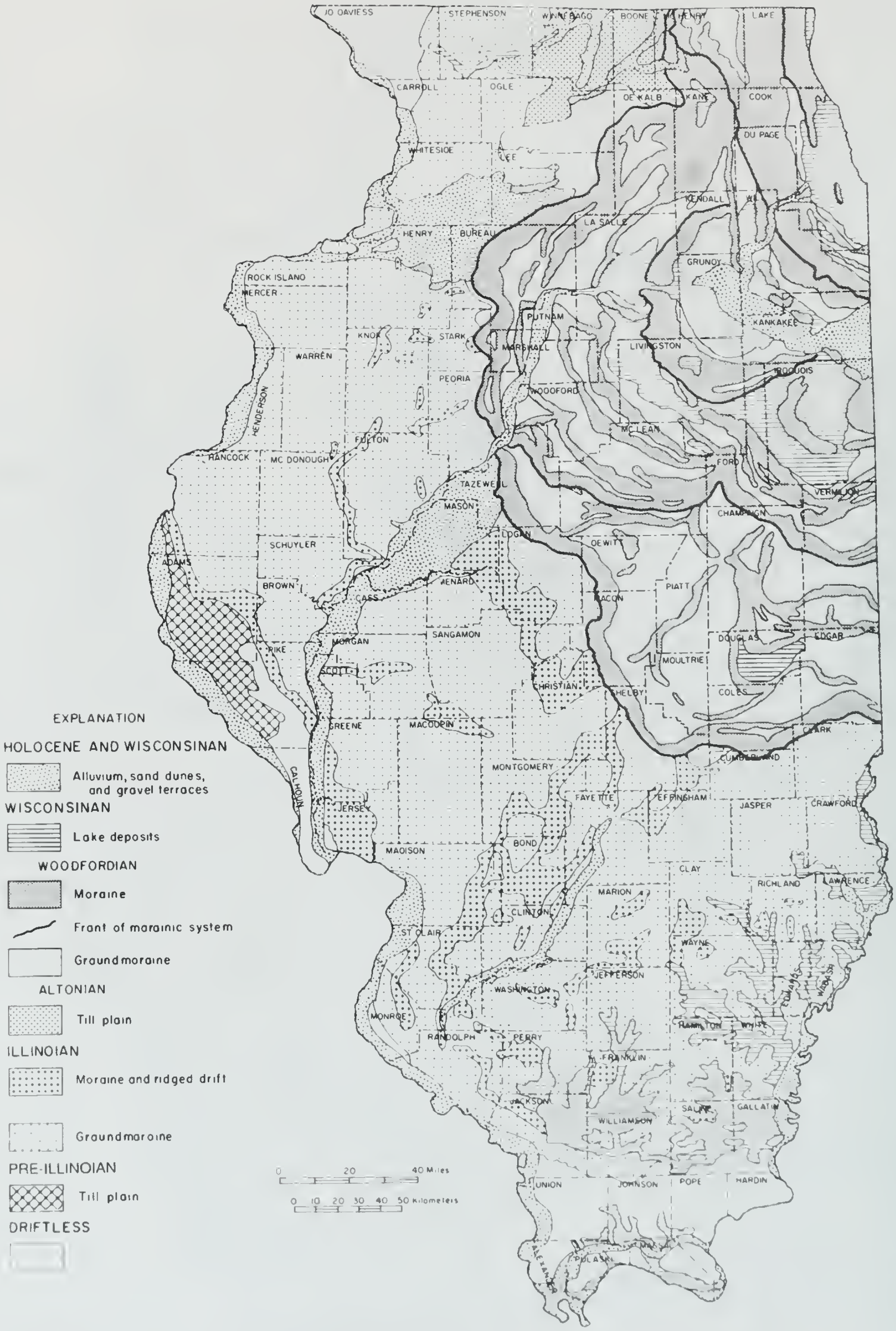


Figure 10 Generalized map of glacial deposits in Illinois (modified from Willman and Frye 1970).

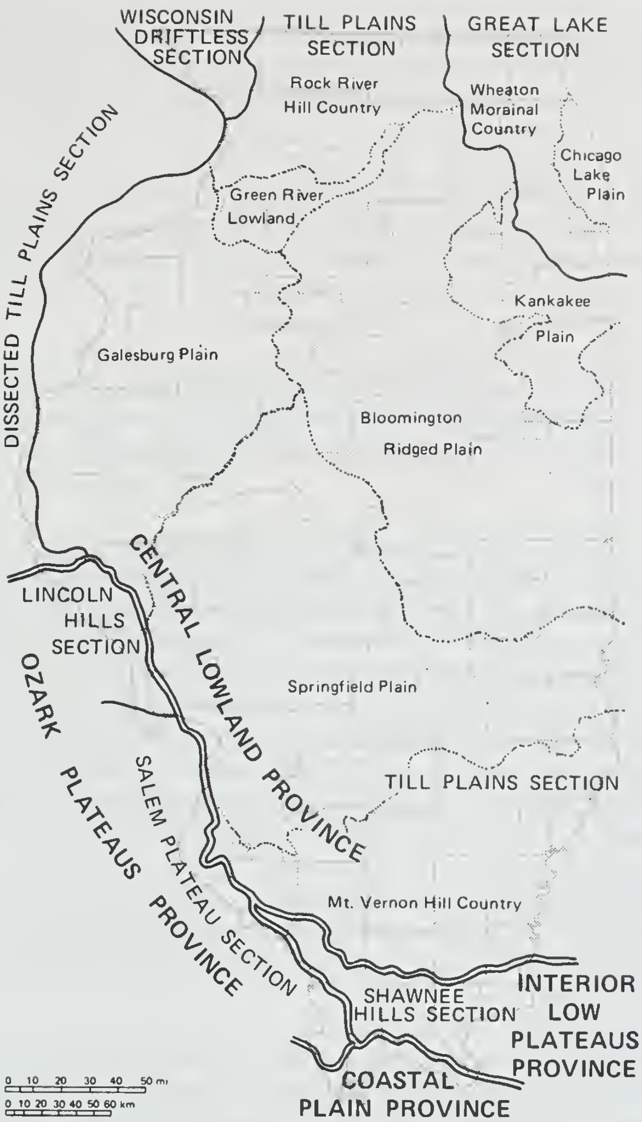


Figure 11 Physiographic divisions of Illinois.

stage of erosion and is characterized by broad till plains that are relatively uneroded, in contrast to the deeply eroded Dissected Till Plains on older drift sheets in Iowa.

According to Horberg (1950) and others (for example, Leighton et al. 1948), an extensive lowland called the central Illinois *peneplain* (a low, nearly featureless, gently undulating land surface) was eroded prior to glaciation into the relatively weak rocks of Pennsylvanian age east and south of the present Illinois River. As glaciation began, streams probably changed from erosion to aggradation; that is, their channels began to fill up with sediments because the streams did not have sufficient volumes of water to carry and move the increased amounts of sediment (a process called alluviation). To date no evidence indicates the early fills in these preglacial valleys ever were completely flushed out of their channels by succeeding glacial meltwater torrents.

Springfield Plain The Springfield Plain, according to Leighton et al. (1948), includes the level portion of the Illinoian drift sheet in central and south-central Illinois. It is distinguished mainly by its flatness and by small, shallow drainageways, as compared with the more sharply incised valleys

of the Galesburg Plain. The south boundary of the district is a line south of which the drift thins and bedrock topography becomes a controlling factor; the west boundary follows the edge of the Illinoian drift. The moraines are low and broad, but they are readily recognized because of their continuity. Many of the hills and ridges appear to be kames and crevasse-fillings related to stagnant ice conditions.

Drainage systems are well developed, and in general, the topographic relief (difference in elevations) is low between the uplands and the master streams. The valleys are relatively shallow. Most of the principal streams have low *gradients* and occupy broad alluviated and terraced valleys; the secondary tributaries have wide V-shaped valleys; and the headwaters, flowing essentially on the till plain, have broad shallow valleys and low gradients.

The Illinoian drift is moderately thick and is underlain by older drift except in areas where the bedrock is close to the surface. Only the larger valleys and uplands of the bedrock surface are reflected in the present topography. Along the southeast side of the Illinois Valley is a belt of thick loess, which thins rapidly to the southeast.

Galesburg Plain The Galesburg Plain, according to Leighton et al. (1948), includes the western segment of the Illinoian drift sheet, a level to undulatory plain with a few morainic ridges that was formed some 250,000 years ago. The Jacksonville moraine, located west of Beardstown, roughly parallels the Illinois Valley; and the Buffalo Hart moraine, located north of Beardstown, extends northward through the central part of the region.

In the Galesburg Plain, the Illinoian drift is generally thick and is underlain by pre-Illinoian glacial deposits, especially along buried preglacial valleys. Most of the irregularities of the preglacial surface were filled in with older drift, so that, only gross features of the bedrock topography are reflected in the present landscape.

The well developed drainage systems flow westward from a central upland into the Mississippi River and eastward and southward into the Illinois River. The larger valleys are generally steep walled, alluviated, and terraced. Much of the district is relatively high above base level, so that the minor valleys are numerous and deep.

Drainage In this field trip area, drainage is controlled by three major rivers: the La Moine, the Sangamon, and the Illinois. The La Moine and the Sangamon flow into the Illinois River, which controls their base levels. The Illinois empties into the Mississippi River near the city of Grafton in Jersey County. Most of the major streams have medium to wide valleys and low gradients (bottom slopes). The creeks and streams within the bluffs generally have narrow valleys and steep gradients. As the streams flow out onto the major river valleys, their gradients change from steep to low.

Relief The highest land surfaces in the field trip area occur atop the bluffs on both the west and east sides of the Illinois River. Elevations of 670 feet above mean sea level (msl) occur on the west side of the Illinois River, just west of the La Grange Lock and Dam, and on the east side of the Illinois River, south of Brick School, which is located at the intersection of North Bluff Springs Road and Chandlerville Road. The highest elevation encountered along the field trip route is 660 feet at the top of the bluff along IL 103 on the west side of the Illinois River. The lowest elevation is 428 feet above msl on the west side of the Illinois River at the junction of IL 100, US 67, and IL 103. The surface relief of the field trip area, calculated as the difference between the highest and lowest elevations, is 242 feet. *Local relief* is most pronounced along the route where the floor of the Illinois River valley meets the bluffs. Along the bluffs, local relief commonly exceeds 200 feet within a distance of a half mile or less.

NATURAL RESOURCES

Mineral production Of the 102 counties in Illinois, 98 reported *mineral* production during 1992, the last year for which records are available. The total value of all minerals extracted, processed, and manufactured in Illinois during 1992 was $2,894,300,000, 0.5% lower than the 1991 total. Minerals extracted accounted for 90% of this total. Coal continued to be the leading commodity, accounting for 64% of the total, followed by industrial and construction materials at 21.4% and oil at 14.2%. The remaining 0.4% included metals, peat, and gemstones. Illinois ranked 13th among the 31 oil-producing states in 1992 and 16th among the 50 states in total production of nonfuel minerals, but it continued to lead all other states in the production of fluorspar, industrial sand, and tripoli.

Schuyler and Brown Counties ranked 34th and 88th, respectively, among all Illinois counties in 1992 on the basis of the value of all minerals extracted, processed, and manufactured. Economic minerals mined in Schuyler County in 1992 included coal, stone (limestone and dolomite), sand and gravel, and crude oil, and those in Brown County include crude oil and clay. Cass County had no reported mineral production for 1992.

Coal production in Schuyler County for 1992 was 629,087 tons, with a cumulative production of 12,752,071. Although no coal is currently being produced in Cass or Brown Counties, their historic cumulative productions are 212,477 and 74,068 tons, respectively.

Coal has been mined primarily from the Colchester Coal in Cass and Brown Counties, and from the Colchester and Springfield Coals in Schuyler County. The only active mine in the area is the Cedar Creek Mine, operated by the Black Beauty Coal Company in Schuyler County.

Petroleum production Over 7 million barrels of oil and an undetermined amount of gas have been produced from Silurian- and Devonian-aged rocks (see fig. 2) in fields west of Beardstown in Adams, Brown, Pike, Schuyler, and McDonough Counties. The oil and gas produced in this area, located on the northwestern flank of the Illinois Basin, comes from relatively shallow depths (less than 650 feet deep,) in comparison to most of the production in Illinois, where the producing zones generally are 2,000 feet or deeper.

Gas The first hydrocarbons in the area were discovered more than 100 years ago, in 1886 at the Pittsfield Gas Field, located in Pike County. The trap is located on or near the crest of the Pittsfield Anticline, an elongate, structurally high dome in the bedrock (see fig. 5). Sixty-eight wells about 285 feet deep produced gas in the field, but production statistics were not kept for this field. Pittsfield Gas Field was abandoned and revived, but the field was finally abandoned in 1930.

Fishhook Gas Field, in Pike County, is located a few miles north of Pittsfield, on an anticlinal structure on the flank of the Pittsfield Anticline (fig. 5). Fishhook was discovered in 1955 and has produced over 2,331.5 million cubic feet of gas. Griggsville Gas Field, in Pike County, lies southeast of the Fishhook field. Discovered in 1982, the field produced 227.2 million cubic feet of gas before it was abandoned in 1986. Other gas fields (such as Beardstown, Adams, and Time fields) reportedly have been discovered in the area, but the ISGS cannot verify commercial production of gas for these fields.

Oil Oil in the area was first discovered in 1914 at the Colmar field in McDonough County. The reservoir is in the Hoing Sandstone, of Devonian age. The only established production in Illinois in the Hoing Sand is from the Colmar-Plymouth field. This field has produced over 5 million barrels of oil from depths around 450 feet, and this 81-year-old field continues to produce about 1,000 barrels of oil each year. The field has undergone many different forms of oil recovery technology, ranging from waterflooding to steam flooding, vacuum pumping, and even a short-lived attempt at underground oil mining.

In the late 1950s and early 1960s, several small Silurian reservoirs were discovered at Kellerville (Adams County), Siloam (Brown County), Buckhorn (Brown County), and Rushville NW (Schuyler County). These fields recovered relatively small volumes of oil and were abandoned in the mid-1960s.

In the early 1980s, after the discovery of Buckhorn East Field in Brown County, the region experienced a pronounced increase in exploratory drilling. Buckhorn East has since been renamed Buckhorn Consolidated and has produced almost 2 million barrels of oil. Siloam and Kellerville Fields, located nearby, were revived as their field limits were extended by new drilling, and have produced about 295,000 and 308,000 barrels of oil, respectively. Several smaller new fields were discovered in Schuyler County in the 1980s, such as Rushville Central and Brooklyn fields, but no fields as prolific as Buckhorn Consolidated have been discovered.

Groundwater Groundwater is a resource frequently overlooked in assessments of an area's natural resource potential. The availability of this resource is essential for orderly economic and community development. More than 35% of the state's 11.5 million citizens and 97% of those who live in rural areas depend on groundwater for their water supply. Groundwater is derived from underground formations called *aquifers*. The water-yielding capacity of an aquifer can only be evaluated by constructing wells into it. After construction, the wells are pumped to determine the quality and quantity of groundwater available for use.

Because thick glacial deposits occur in this area, sand and gravel deposits are common throughout most of the area, especially along the major rivers and in the buried bedrock valleys. Thick, permeable deposits of sand and gravel occur along the major rivers, and most of these deposits yield large amounts of water. In addition to the groundwater aquifers, a number of farms and rural homesteads obtain their water supplies from manmade lakes. The city of Beardstown withdraws its municipal water supply from the Illinois River.

GUIDE TO THE ROUTE

Assemble at the southwest parking lot of the Beardstown High School (SW, SW, SW, Sec. 15, T18N, R12W, 3rd P.M., Cass County, Beardstown 7.5-minute Quadrangle [40090A4]*). We'll start calculating mileage at the intersection of State Street and 15th Street.

You must travel in the caravan. Please drive with headlights on while in the caravan. Drive safely but stay as close as you can to the car in front of you. Please obey all traffic signs. If the road crossing is protected by an Ilinois State Geological Survey (ISGS) vehicle with flashing lights and flags, please obey the signals of the ISGS staff directing traffic. When we stop, park as close as possible to the car in front of you and turn off your lights.

Private property Some stops on the field trip are on private property. The owners have graciously given us permission to visit on the day of the field trip only. Please conduct yourselves as guests and obey all instructions from the trip leaders. So that we may be welcome to return on future field trips, follow these simple rules of courtesy:

- Do not litter the area.
- Do not climb on fences.
- Leave all gates as you found them.
- Treat public property as if you were the owner—which you are!

When using this booklet for another field trip with your students, a youth group, or family, remember that *you must get permission from property owners or their agents before entering private property.* No trespassing please.

Twelve USGS 7.5-Minute Quadrangle maps (all available from the ISGS) provide coverage for the area of the field trip: Arenzville East, Arenzville West, Ashland, Beardstown, Chandlerville, Clear Lake, Cooperstown, Newmansville, Ripley, Rushville South, Versailles, and Virginia.

Miles to next point	Miles from start	
0.0	0.0	Line up in the southwest parking lot of the Beardstown High School at the corner of State Street and 15th Street. Leave the parking lot and turn right onto 15th Street. When you make the turn, Jefferson Street is on the left.
0.1	0.1	STOP (3-way): Intersection of East 15th Street and Monroe Street. CONTINUE AHEAD.
0.05	0.15	T-intersection from the left: Clay Street. CONTINUE AHEAD.
0.05	0.2	T-intersection from the left: Edwards Street. CONTINUE AHEAD.
0.05	0.25	T-intersection from the left: Bay Street. CONTINUE AHEAD.

* The number in brackets [40090A4] after the topographic map name is the code assigned to that map as part of the National Mapping Program. The state is divided into 1 blocks of latitude and longitude. The first two numbers refer to the latitude of the southeast corner of the block; the next three numbers designate the longitude. The blocks are divided into 64 individual 7.5-minute quadrangles; the letter refers to the east–west row from the bottom and the last digit refers to the north-south column from the right.

0.05	0.3	CAUTION: Cross three railroad tracks, unguarded with signal lights. Burlington-Northern railroad.
0.1	0.4	STOP (4-way): Intersection of East 15th Street and Wall Street. TURN LEFT onto Wall Street. Pass by intersections of East 14th, 13th, 12th, 11th, 10th, and 9th streets.
0.5	0.9	STOP (4-way): Intersection of East 8th Street and Wall Street. CONTINUE HEAD. Pass by intersections of East 7th, 6th, and 5th streets.
0.2	1.1	STOP (4-way): Intersection of East 4th Street and Wall Street. TURN RIGHT onto East 4th Street. Pass by intersections of Canal, Oak, and Walnut Streets.
0.25	1.35	STOP (2-way): 5-point intersection of East 3rd Street, Levee Road, East 4th Street, and Railroad Street. CONTINUE AHEAD on East 4th Street, which curves to the right and becomes Chandlerville Road (1000N). Heading east.
0.15	1.5	View of backwaters behind the Beardstown Levee. Water is pumped over the levee during periods of high water.
0.1	1.6	Oak Grove Cemetery to the right.
0.05	1.65	T-intersection from the right: 850E. CONTINUE AHEAD.
0.4	2.05	T-intersection from the left: Duck Slough Road, 900E. TURN LEFT. Road is unmarked. After making the turn, notice the flat topography of the land. You are driving on top of the Beardstown terrace. This terrace marks the level of an older floodplain of the Illinois and Sangamon Rivers. The Beardstown terrace ranges in elevation from 436 to 445 feet above sea level and is about 10 feet higher than the modern Illinois River floodplain.
0.45	2.5	To the left, directly in front, and to the right, you can see the levee system along Lost Creek. Lost Creek flows into Muscooten Bay.
0.05	2.55	Road curves to the right.
0.45	2.9	Lost Creek levee system. Pull over to the right side of the road. Do not park on the bridge.

STOP 1 We'll view and discuss the construction and development of levees, the topography of flood plains and terraces, the width of the Ancient Mississippi River Valley, the modern Illinois River, and the rechannelization and diversion of the Sangamon River.

0.0	2.9	Leave stop 1. CONTINUE AHEAD.
0.2	3.1	Cross drainage ditch.
0.3	3.4	Center-pivot irrigation system on the left side of the road. As you continue across the old floodplain of the Ancient Mississippi River, you will see many more of these center-pivot irrigation systems. These water wells produce between 500 and 3,000 gallons per minute depending on their depth and

		design. This should give you an idea of the amount of water stored in the sand and gravel deposits of the Ancient Mississippi River Valley.
0.5	3.9	The farmstead is located on a small rise. This is a sand dune. As you drive by, take a look at the soil. Where exposed, the soil is very sandy.
0.4	4.3	Road curves to the right. The road is now called Clear Lake Road.
0.15	4.45	T-intersection from the left: Phelps Ditch Road. CONTINUE AHEAD. Three center-pivot irrigation systems on the right side of the road, and one on the left.
0.65	5.1	T-intersection from the right: Schewe Lane (unmarked). CONTINUE AHEAD.
0.25	5.35	Center-pivot irrigation system on the right.
0.75	6.1	Road curves 45° to the right. Good view straight ahead of the bluffs, which mark the easternmost edge of the valley of the Ancient Mississippi River.
0.3	6.4	Road curves 45° to the left.
0.3	6.7	T-intersection from the left: 1250E (unmarked). CONTINUE AHEAD.
0.2	6.9	Road curves 90° to the right. Good view of the bluffs.
0.2	7.1	T-intersection from the left: Krohe Lane (1120N). CONTINUE AHEAD.
0.8	7.9	Cross Califs Ditch, which also has a set of levees. Notice that the tops of the levees here are not as far above the floodplain as the ones along Lost Creek, even though the tops of the levees are at the same elevation. This is because the elevation of the floodplain here is higher; therefore, a lower levee is needed to maintain the same elevation as the levees closer to the Illinois River. The height of levees decreases as you move away from the Illinois River.
0.45	8.35	STOP (2-way): Intersection of Clear Lake Road (1270E) and Chandlerville Road (100N). TURN LEFT onto Chandlerville Road. On the southwest corner of the intersection is Brick School, constructed in 1927, which was a staging area for sandbagging during The Great Flood of 1993.
0.3	8.65	Exposure of Wisconsin Episode Peoria Loess to the right in the bluffs.
0.25	8.9	T-intersection from the right: Kuhlman Hill Road (unmarked). CONTINUE AHEAD.
0.15	9.05	Cross Califs Ditch.
1.25	10.3	T-intersection from the left: 1450E. CONTINUE AHEAD. Notice the dissected nature of the bluffs, a mixture of sharply rolling uplands cut by steep ravines and some wider valleys. Also, along the bluffs in many places, ponds have been formed by constructing earthen dams across the ravines.
0.5	10.8	Hager Cemetery on the left.

1.3	12.1	T-intersection from the right: Shilo Road. CONTINUE AHEAD.
1.1	13.2	T-intersection from the right: Hickory Road. Immediately cross Schadd Ditch and another T-intersection from the left: Gum Town Road (1730E). CONTINUE AHEAD.
0.5	13.7	Cross Indian Run Creek.
1.0	14.7	Good view of the floodplain to the left. The tree-line in the distance to the north outlines the course of the Sangamon River.
0.4	15.1	Cross Job's Creek. The valley cut into the bluff by Job's Creek is among the wider ones in the area.
1.05	16.15	T-intersection from the left: Old River Road (2000E). CONTINUE AHEAD.
0.50	16.65	The group of pine trees to the left is growing on a sand dune. The dune forms a topographic high on the floodplain.
0.85	17.5	CAUTION: Stop (1-way): T-intersection of Chandlerville Road (1110N) and State Route 78. TURN LEFT. Use extreme caution: fast moving traffic from the right is coming down a steep hill.
0.4	17.9	T-intersection from the right: Finn Lane. CONTINUE AHEAD.
0.7	18.6	Cross Panther Creek.
0.35	18.95	Entering community of Chandlerville, population 800. Slow down. PREPARE to turn right.

The following was provided by Wayne Nelson of the Chandlerville Water Supply Department. The village of Chandlerville was incorporated in 1836 and, at one time, was a stop on the Jacksonville & Havana Railroad. It is located between the Sangamon River to the north and the bluffs to the south.

The Chandlerville Water Department serves a population of approximately 680. In the early 1980s, nitrate levels in the water department's only well began to climb and by the mid-1980s had exceeded the maximum allowable concentration of 10 mg/L. Tests conducted by the IEPA in 1989 showed presence of several agri-chemicals including Atrazine (Aatrex), Alachlor (Lasso), Metolachlor (Dual), and Metribuzin (Sencor). At the time there were no drinking water standards for these chemicals. When standards were enacted, Chandlerville's water was in noncompliance. In August 1991, the village board signed a letter of commitment with the IEPA and the Illinois Attorney General to proceed with a new water source. The letter directed the village to take the following steps in addition to the major step of installing new wells:

1. Weekly nitrate sampling.
2. Free bottled water to infants under six months of age.
3. Public notice on a quarterly basis.
4. Notification of area physicians regarding agri-chemical levels.
5. Posting of signs in schools and restaurants stating the presence of agrichemicals in the finished water.

The village board obtained a Community Development Assistance Program (CDAP) grant to install two new wells. Engineering studies, computer mapping, and test holes ensure a safe source of raw water.

The village's two new wells went on line in August 1993. Well no. 3 is 66 feet deep and well no. 4 is 62 feet deep. The contaminated well, only 37 feet deep, was located approximately 700 feet from an agri-chemical storage facility and was drilled in a sand and gravel aquifer. Tillable fields that were treated with agrichemicals surrounded the old well site.

The new wells show no sign of any regulated chemicals, although iron levels are high enough that water plant personnel add potassium permanganate to oxidize and remove the iron from the finished water.

0.05	19.0	CAUTION: Intersection of English Avenue and Chandlerville Road. TURN RIGHT at sign marking the western branch of the Lincoln Heritage Trail.
0.1	19.1	STOP (1-way): Intersection of South Main Street and River Street. TURN RIGHT onto South Main Street.
0.05	19.15	STOP (3-way): Intersection of Division Street and South Main Street. CONTINUE AHEAD.
0.05	19.2	Intersection with Douglas Street. CONTINUE AHEAD.
0.1	19.3	T-intersection from the left: Cottage Avenue and South Main Street. TURN LEFT onto Cottage Avenue.
0.2	19.5	T-intersection from the left: South Bluff Street. CONTINUE AHEAD.
0.1	19.6	Chandler Cemetery is on the left. Panther Creek is to the right.
0.3	19.9	Entering Site M State Conservation Area. The road is now called Creek Road.
0.1	20.0	To the right, along the south side of Panther Creek, a slump in the bluff has exposed some Peoria Loess.
1.0	21.0	Loess exposed on the left side of the road. Also a good view of the valley that has been cut by Panther Creek. To the right is a Sustainable Agriculture Research and Demonstration Area.
0.2	21.25	T-intersection from the right: Hermann Road. CONTINUE AHEAD.
0.3	21.5	Note: to the right, Panther Creek is flowing along the south side of the valley up against the bluffs. In the past, this creek has meandered back and forth within the area outlined by the flat terrace located immediately to the right.
0.35	21.85	T-intersection from the right: Creek Road. TURN RIGHT.
0.15	22.0	Road curves sharply to the left. Note: the steel pillars to the right mark the location where a bridge once crossed Panther Creek. As soon as you make the left turn, the road curves back to the right. Cross the ford on Cox Creek.
0.1	22.1	Pull over to the far right side of the road.

STOP 2a We'll view and discuss the stream geomorphology at the confluence of Cox and Panther Creeks, post-European sedimentation, and erosion control measures.

0.0	22.1	Leave stop 2a. CONTINUE AHEAD.
0.2	22.3	To the right, on the other side of Panther Creek, you can see the position of the old roadbed and a large slump scarp on the bluff.
0.2	22.5	Excellent view of the slump scarp on the bluff.
0.1	22.6	Pull over to the far right side of the road.

STOP 2b We'll view and discuss the large slump feature located along Panther Creek and the glacial deposits of the Illinois and Wisconsin Episodes.

0.0	22.6	Leave stop 2b. CONTINUE AHEAD.
0.75	23.35	Road curves 90° to the left.
0.4	23.75	CAUTION: Road crosses a very steep drainage ravine that flows toward Cox Creek.
0.05	23.8	Road curves 90° to the right.
0.7	24.5	Road curves 90° to the left.
0.3	24.7	Notice the flat to slightly rolling topography. This gives you an idea of how the landscape looked before erosion.
0.15	24.85	T-intersection from the right: Gurney Road. CONTINUE AHEAD.
0.1	24.95	T-intersection from the left: Gurney Road (2600E). CONTINUE AHEAD.
0.4	25.35	Small drainage ditch developed on top of the bluff; flow is to the north.
0.35	25.7	STOP (1-way): T-intersection of Creek Road (850N) and County Highway 11 (2670E). TURN RIGHT onto County Highway 11.
0.7	26.4	Road curves to the right. T-intersection from the left: Wolf Road (780N) on the south side of the curve. CONTINUE AHEAD.
0.3	26.7	T-intersection from the left: Cox Road. CONTINUE AHEAD.
0.35	27.05	T-intersection from the left: CONTINUE AHEAD.
0.15	27.2	T-intersection from the right: CONTINUE AHEAD.

0.4	27.6	Road curves 90° to the left. T-intersection in the middle of the curve from the right. CONTINUE AHEAD.
0.3	27.9	Descending into the valley of Panther Creek.
0.2	28.1	Cross Panther Creek.
0.25	28.35	T-intersection from the right. CONTINUE AHEAD.
0.05	28.4	Back up on top of the loess-covered bluffs. This probably is very close to the original topography and elevation of the land before erosion dissected the upland.
0.45	28.85	Road curves 90° to the right. T-intersection from the south in the middle of the curve. CONTINUE AHEAD on County Highway 11.
0.25	29.1	Road curves 90° to the left. Road is now called Fox Road.
0.8	29.9	Road curves 90° to the right. T-intersection from the left in the middle of the curve. CONTINUE AHEAD. Road is now called Gridley Road (550N).
0.45	30.35	Approaching Y-intersection. BEAR LEFT.
0.15	30.5	Stop (1-way): T-intersection with Philadelphia Road. TURN LEFT (south).
0.4	30.9	CAUTION: Crossroad intersection of Gilbert Road (500N) and Philadelphia Road. CONTINUE AHEAD. 2-way stop is from right and left.
0.1	31.0	Old windmill on the left side of the road.
1.3	32.3	CAUTION: Approaching intersection with IL 125.
0.2	32.5	STOP (1-way): Intersection of Philadelphia Road and IL 125. TURN RIGHT onto IL 125. After making the turn, you will be entering the village of Philadelphia. We will follow IL 125 back to Beardstown.
2.0	34.5	T-intersection from the right: Sugar Grove Road. Sign marking historic site of Allendale Home, located to the right. Notice that the landscape along this portion of the trip is very flat, with only slight undulations in the topography; no large drainageways have developed. The road is built along the drainage divide. Rain falling north of the road flows north, and rain falling south of the road flows south.
2.4	36.9	T-intersection from the left: Beardstown Road. CONTINUE AHEAD.
0.6	37.5	Entering the village of Virginia, population 1800.
0.5	38.0	STOP (4-way) with flashing red light: Intersection of IL 78 and IL 125. CONTINUE AHEAD. Just before the intersection is a manmade lake on the right side of the road.
3.05	41.05	Shiloh Presbyterian Church on the right side of the road. Note the classic architecture.

0.6	41.65	Notice the difference in the topography between this spot and where you first entered IL 125 at Philadelphia, where it was fairly flat. You are entering a large valley that has eroded into the bluff. The landscape is characterized by rolling topography and is dissected by small drainage ravines. On the left side of the road is Lost Creek, which is one of the major drainageways in the area. This is the same creek we saw at stop 1.
0.85	42.5	Large slump blocks in exposures of Peoria Loess on the left side of the road. From this point, until we reach the edge of the bluffs and enter the Illinois River valley, you will see numerous exposures of loess along the roadside. Look near the large barns and houses constructed next to the bluffs. Several of these barns and houses have very steep exposures of loess behind them. Also note that where IL 125 is on top of the bluff near the town of Virginia, it is fairly straight. Now that the road is in this valley, however, it curves very gently to the right and left. This is because the road is located on the floodplain and is generally parallel to the course of Lost Creek valley.
3.2	45.7	Entering the community of Bluff Springs. North Bluff Springs Road is to the right.
0.3	46.0	Cross bridge over Lost Creek.
0.2	46.2	Notice the difference in topography. It's flat. We are back on the floodplain of the Ancient Mississippi River.
0.85	47.05	Crossroad intersection: Deer Path Road. CONTINUE AHEAD.
1.90	48.95	CAUTION: Approaching stoplight. Be prepared to stop.
0.2	49.15	STOPLIGHT: Intersection of IL 125 and Arenzville Road. CONTINUE AHEAD.
0.3	49.45	T-intersection from the right: Beardstown Road. TURN RIGHT.
0.1	49.55	Beardstown city limits.
0.5	50.05	STOP (4-way): Intersection of East 15th Street and Wall Street. CONTINUE AHEAD.
0.5	50.55	STOP (4-way): Intersection of East 8th Street and Wall Street. CONTINUE AHEAD.
0.2	50.75	STOP (4-way): Intersection of East 4th Street and Wall Street. TURN RIGHT.
0.2	50.95	STOP (2-way): 5-point intersection of East 3rd Street, Levee Road, East 4th Street, and Railroad Street. TURN LEFT and drive up onto Levee Road and TURN LEFT.
0.15	51.1	Levee Road curves 90° to the right. Meyers Pond is to the right.
0.25	51.3	Levee Road curves 90° to the left. Park your car in the middle of the levee road.

STOP 3 Here we'll view and discuss the Illinois River, diversion of the Sangamon River, and sedimentation of Muscooten Bay and Meyers Pond.

LUNCH: Are you hungry? Follow Levee Road around to the park for lunch.

Note: There are two large parking lots in the park. We use both of these and the circle drive between the two parking lots. After we leave the park, we will reset our trip odometers to 0.0.

0.0	0.0	Exit park using the road parallel to railroad tracks. Restart milage at the intersection of Sangamon Street and East 2nd Street, at the south-southwest corner of the park.
0.05	0.05	Intersection with East 3rd Street. CONTINUE AHEAD.
0.05	0.1	STOP (2-way): Intersection of East 4th Street and Sangamon Street. TURN RIGHT onto to East 4th Street and cross a single set of railroad tracks. CAUTION: unguarded crossing.
0.05	0.15	CAUTION: Cross a second set of unguarded railroad tracks.
0.05	0.2	Intersection of Base Street. CONTINUE AHEAD.
0.05	0.25	STOP (4-way): Intersection of Edwards Street. CONTINUE AHEAD.
0.25	0.5	STOP (4-way): Intersection of West 4th and State Street. TURN LEFT.
0.1	0.6	STOP (4-way): Intersection of State Street and West 6th Street. TURN RIGHT.
0.65	1.25	CAUTION: STOP (2-way): Intersection of West 6th Street and US 67 & IL 100. TURN RIGHT. This road the western branch of the Lincoln Heritage Trail.
0.15	1.4	Enter bridge crossing the Illinois River. Note: to the right and left, the barge traffic on the river is usually pretty heavy. To the right is an old iron railroad drawbridge, which is still in use. To the left is Grape Island, covered with trees, in the middle of the Illinois River. At the middle of the river, you enter Schuyler County and leave Cass County. As you approach the western end of the bridge, you get a good view of the flat floodplain of the Illinois River and the bluffs to the west.
1.3	2.7	STOP (4-way) with flashing red lights: Intersection of IL 103, IL 100, and US 67. TURN LEFT onto IL 103, the western branch of the Lincoln Trail. To the right is IL 100 and straight ahead is US 67. Elevation at the intersection is 428 feet above sea level.
0.5	3.2	Cross Coal Creek Ditch. A good view of the bluffs to the right on the western side of the Illinois River. Water from Coal Creek is pumped over the levee along the Illinois River. Good view of the levee along the Illinois River to your left.
0.9	4.1	Cross drainage ditch.

0.4	4.5	View of Crane Creek levee directly ahead.
0.5	5.0	Cross Crane Creek Ditch. Notice that this ditch has levees on both sides. Water from Crane Creek Ditch empties directly into the Illinois River; elevation of levee is 452 feet above sea level.
0.55	5.55	T-Intersection from the left: Sandy Bend Road (2100E). CONTINUE AHEAD.
0.65	6.2	T-intersection from the left 2040E: CONTINUE AHEAD.
0.1	6.3	Road starts to ascend the bluff.
0.15	6.45	Intersection of Bluff Road 2010E: CONTINUE AHEAD.
0.45	6.9	The road flattens out. You are now on top of the bluff. Elevation is 610 feet above sea level, approximately 180 feet above the floodplain below. To the left is a good view of the Illinois River valley and the bluffs to the south. The large flat floodplain between the bluffs is occupied by the La Moine River.
0.45	7.35	T-Intersection from right: Water Reservoir Road. CONTINUE AHEAD.
0.25	7.6	Topography at this point on the top of the bluffs is gently rolling with large valleys between the higher portions of the bluffs. Several northeast-trending valleys cut into the top of the bluffs were eroded by glacial meltwater during the late Wisconsin Episode.
0.7	8.3	A small lake to the right was formed by damming the left fork of Crane Creek. This creek possibly follows one of the glacial meltwater channels.
0.25	8.55	Another low drainage ditch.
0.25	8.8	Intersection of Sugar Grove Road (1780E) and IL 103 (400N): CONTINUE AHEAD. Entering and leaving the community of Sugar Grove. Sugar Grove church on the northwest corner of the intersection is to the right.
0.55	9.35	T-intersection from the right: Urven Road (1730E). CONTINUE AHEAD.
0.25	9.6	T-intersection from the left: La Grange Lock Road (1700E). Large valley to the right. Exposures of Pleistocene deposits to the right. To the right is a small pond formed by an earthen dam across the drainage ravine.
0.4	10.0	Road makes a sharp descent into the valley of Town Branch, one of the large ravines that have eroded into the bluff.
0.4	10.4	Cross Town Branch, which flows southwest to the La Moine River + 0.4 miles.
0.2	10.6	Ascending the valley of Town Branch.
0.4	11.0	Road curves to the left.
0.3	11.3	Road curves to the right.
0.2	11.5	CAUTION: Approaching stop.

0.2	11.7	STOP (1-way): Intersection of US 24 and IL 103. CAUTION: Fast-moving traffic. TURN LEFT onto US 24. Immediately after you make the turn, there is a road to the right. CONTINUE AHEAD (southwest).
0.2	11.9	T-intersection from the right: Vancil Road. CONTINUE AHEAD.
0.2	12.1	Pull over and park vehicles on the far right edge of the road. CAUTION: fast moving traffic.

STOP 4 Ripley roadcut. We'll view and discuss a classic example of an erosional unconformity between the Mississippian and Pennsylvanian Systems of strata.

0.0	12.1	Leave stop 4.
0.1	12.2	Cross bridge over the La Moine River. Leaving Schuyler County and entering Brown County. Notice the terrace developed along the La Moine River on the southwest side of the river.
0.2	12.4	Entering Ripley, population 100.
0.1	12.5	T-intersection from the right: 1465E. CONTINUE AHEAD.
0.2	12.7	T-intersection from the right: CONTINUE AHEAD.
0.05	12.75	T-intersection from the left: CONTINUE AHEAD. Prepare to TURN RIGHT.
0.05	12.8	T-intersection from the right: TURN RIGHT. As soon as you turn, take the left fork in the road.
0.1	12.9	T-intersection from the right: CONTINUE AHEAD.
0.1	13.0	Road curves 90° to the left. After the turn, to the right is Cannon Pottery. Notice the kiln outside the barn.
0.05	13.05	Road curves 90° to the right.
0.1	13.15	T-intersection: 1400E and 1230N. TURN RIGHT. As soon as you turn right, the road makes a sharp turn to the left.
0.25	13.4	Pull over to the far right side of the road. Do not park on the bridge. The small creek flows north where it enters the La Moine River approximately 0.6 miles north of the road.

STOP 5 Clay pit west of Ripley. We'll view and discuss the lower Pennsylvanian Tradewater Formation. At this stop, you will have an opportunity to collect gypsum crystals.

0.0	13.4	Leave stop 5. CONTINUE AHEAD.

0.6	14.0	Stop (1-way): T-intersection: 1320E and 1250N. TURN LEFT. Intersection is not marked.
0.45	14.45	Stop (1-way): T-intersection: 1200N and 1315E. TURN LEFT onto 1200N heading east.
0.75	15.2	CAUTION: Stop (2-way): Crossroad intersection of US 24 (1385E) and 1200N. USE CAUTION and cross US 24. CONTINUE AHEAD.
0.15	15.35	T-intersection from the right: 1400E and 1200N. TURN RIGHT onto 1400E. Sign indicating Cooperstown 6 miles.
0.5	15.85	Road curves to the left.
0.2	16.05	Cross Logan creek. Mississippian limestone is exposed to the left on the outside meander (cutbank) of the creek.
0.3	16.35	Road curves to the right.
0.3	16.65	Road curves 90° to the right and then 90° back to the left.
0.6	17.25	Farm lane on the right. CONTINUE AHEAD.
0.75	18.0	Crossroad intersection of 950N and 1400E. TURN LEFT onto 950N. Red brick house on the northeast corner of the intersection.
0.5	18.5	T-intersection from the left: 1450E. CONTINUE AHEAD.
0.25	18.75	T-intersection from the right: 1475E and 950N. CONTINUE AHEAD. Note the rolling topography in this area. A small creek parallels the road.
0.4	19.15	Road makes sharp turn to the right.
0.3	19.45	Cross bridge over small unnamed creek. Creek flows northeast toward the La Moine River. Pull over as far as possible. Do not park on the bridge. CAUTION: Traffic approaching bridge has limited visibility.

STOP 6 "Cooperstown Creek." We'll view and discuss the Mississippian limestones and shales exposed to the right and left along the creek. A set of three small waterfalls is located to the left. This stop will give you an excellent opportunity to collect fossils.

0.0	19.45	Leave stop 6: The road curves to the right after you cross the bridge and heads south (1550E).
0.85	20.3	Y-intersection from the left: 1550E and 850N. TURN LEFT onto 850N, and prepare to stop at STOP sign. CONTINUE AHEAD.
0.15	20.45	Entering the village of Cooperstown.
0.3	20.75	T-intersection from the left: 1600E and 850N. TURN LEFT onto 1600E. Heading north towards the La Moine River.

0.4	21.15	Peoria Loess exposed. Road cuts through a small hill.
0.2	21.35	Road curves uphill to the right.
0.1	21.45	To the left is a large ravine. The road now cuts through a loess section. Mississippian rocks are exposed at the bottom of the ravine.
0.2	21.65	Outcrop exposed on the left side of the road. Another large ravine. Note that as we get closer to the La Moine River, the valleys are larger and more deeply eroded into bedrock.
0.5	22.15	Road curves 90° to the left and immediately 90° to the right.
0.2	22.35	The road is now traversing an old terrace level of the La Moine River, which is immediately to the left.
0.35	22.7	T-intersection with La Grange Lock Road. TURN LEFT and cross bridge over La Moine River. Northwest corner of the bridge is marked as 1730E and 070N. Note: we are traveling away from the La Grange Lock and Dam on the Illinois River, which is about 4 miles south of this intersection. The road to the right runs along the base of the bluff.
0.4	23.1	Crossroad intersection: Briney Lane (100N). CONTINUE AHEAD.
0.45	23.55	T-intersection from the right: Sandy Bend Road (150N). TURN RIGHT onto Sandy Bend Road.
0.2	23.75	Langford Cemetery is to the left. Pull over to the right side of the road.

STOP 7 We'll view and discuss the exposure of Peoria Loess, Roxana Silt, and Sangamon Soil, which is located just past the cemetery.

0.0	23.75	Leave stop 7: CONTINUE AHEAD.
0.05	23.8	T-intersection from the right at the base of the road cut. Good view of the broad floodplain of the Illinois River. To the right is the La Moine River. Directly ahead to the east, the trees mark the path of the Illinois River. The large concrete structure straight ahead is a pumping station at Brigs Landing, where water from the drainage ditches in the floodplain directly in front of us is pumped over the levees.
0.25	24.05	T-intersection from the left: Sugar Grove Road (1780E). TURN LEFT. Unmarked intersection.
0.35	24.4	Cross small drainage creek.
0.3	24.7	SLOW DOWN: Farm house on the left side of the road. Nice view of the Illinois River valley to the right.
0.5	25.2	Large erosional ravine to the left.

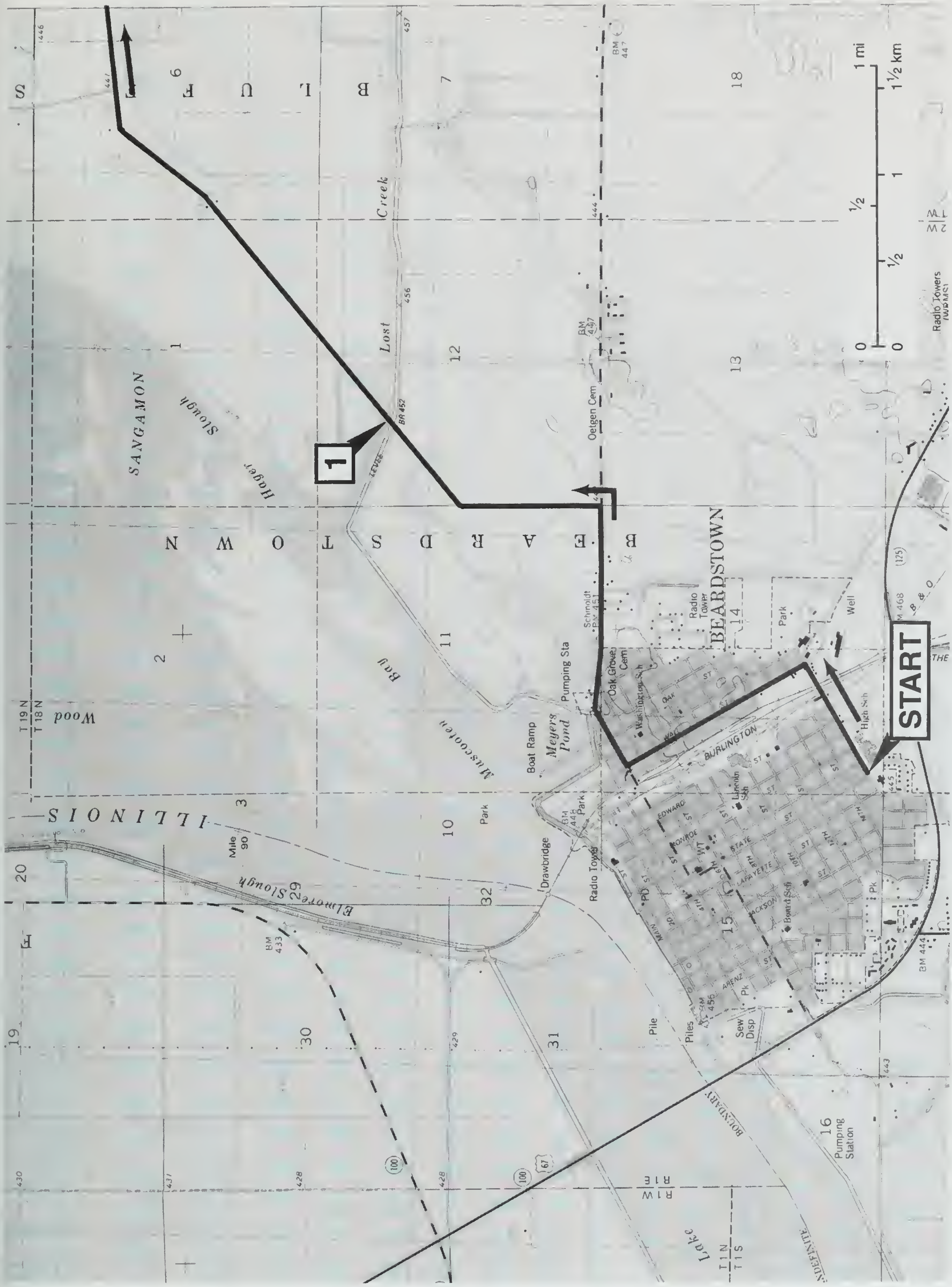
0.4	25.6	T-intersection from the right: Roberts Road. Road makes sharp 90° turn to the left. TURN LEFT.
0.1	25.7	T-intersection from the right: Sugar Grove Road. CONTINUE AHEAD on Roberts Road.
0.35	26.05	Road makes a sharp 90° turn to the left.
0.3	26.35	Road makes a sharp 90° turn to the right.
0.35	26.7	STOP (1-way): T-intersection with La Grange Lock Road. TURN RIGHT. Road immediately curves to the left. Unmarked intersection.
0.15	26.85	CAUTION: Road curves to the right. T-intersection from the left in the middle of the curve:Quarry Road (270N). TURN LEFT onto Quarry Road.
0.5	27.35	T-intersection from the right: Burns Road (1660E). CONTINUE AHEAD.
0.05	27.4	T-intersection from the left: Watkins Lane (1650E). CONTINUE AHEAD.
0.4	27.8	Quarry is to the left. CONTINUE AHEAD.
0.2	28.0	Gate across the road. Note the old red brick farmhouse on top of the bluff to the right.

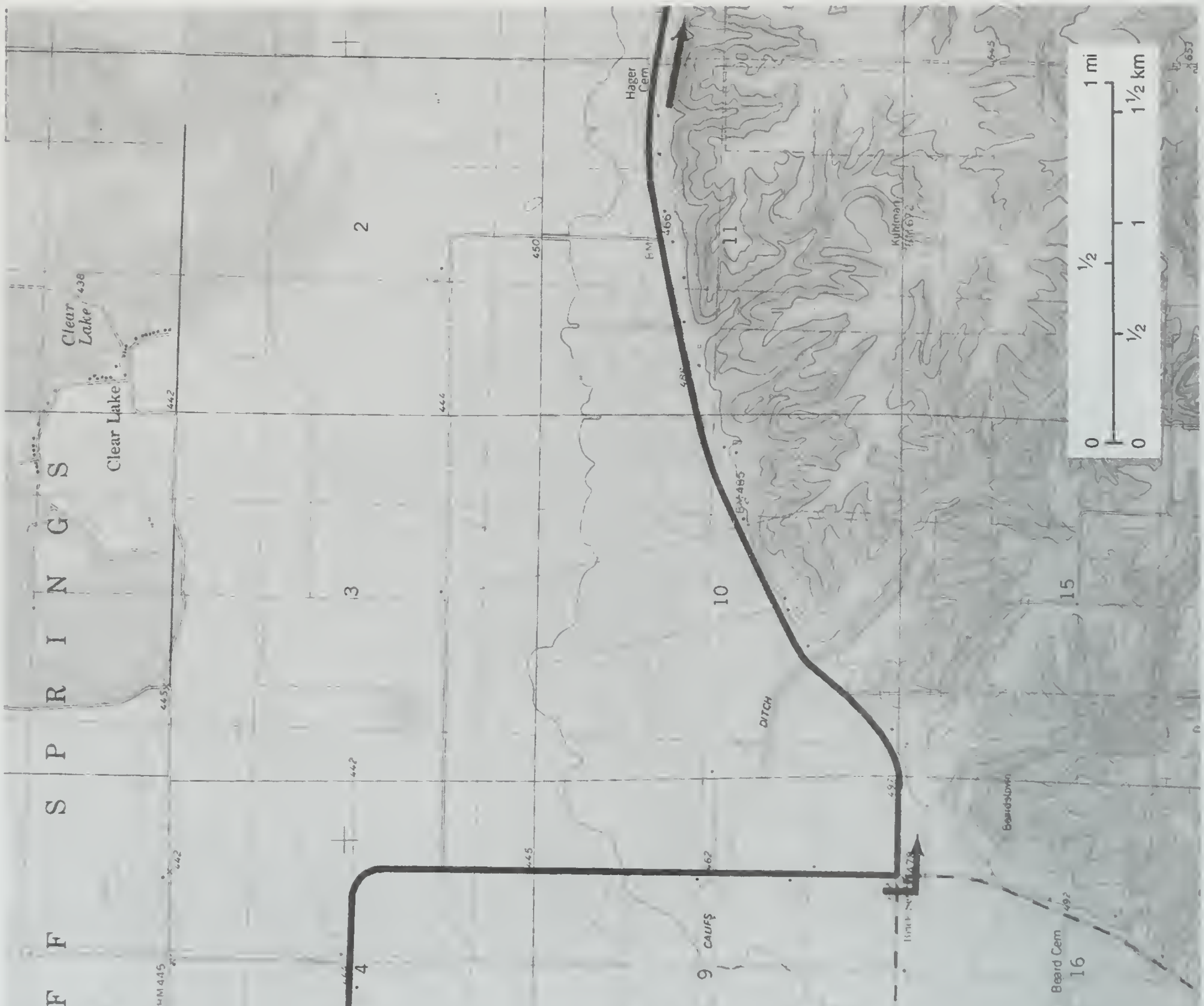
STOP 8 Ward Quarry. We'll stop and open the gate. Stay in your vehicles. Follow road to the left along the base of the bluff to the entrance to the quarry. This is the last stop of the day. At this stop you'll be able to observe exposures of Mississippian and Pennsylvanian rock units, which are overlain by Quaternary deposits.

0.5	28.5	Leave stop 8: The following road log will lead you back to IL 103. From the quarry, follow Quarry Road (270N) until you reach La Grange Lock Road (1700E). TURN LEFT. Follow La Grange Lock Road (1700E) heading north about 1.3 miles until you come to IL 103, which is (400N). If you turn right at this junction, you will be heading towards Beardstown. If you turn left, you will be heading towards US 24.

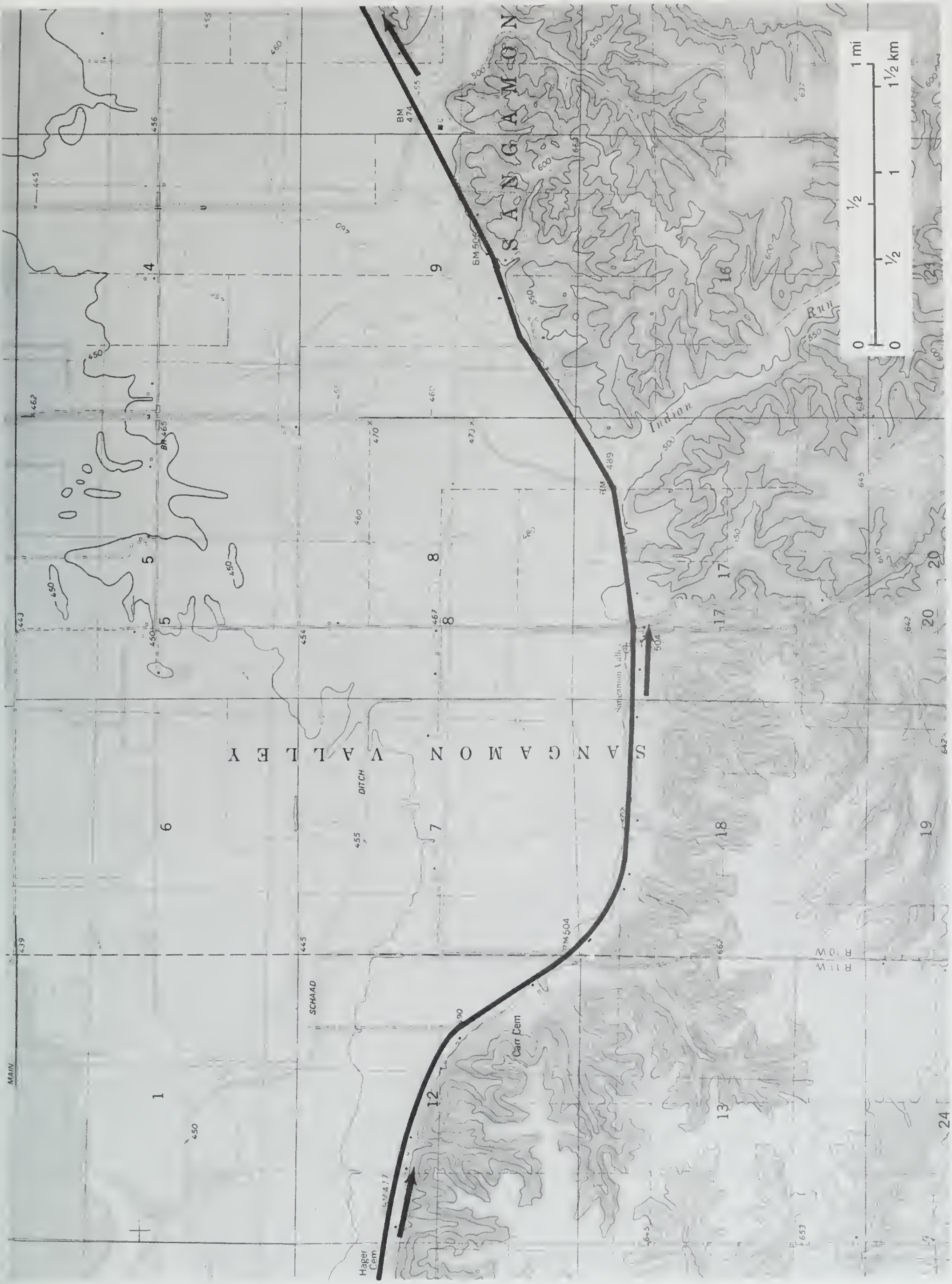
END OF FIELD TRIP

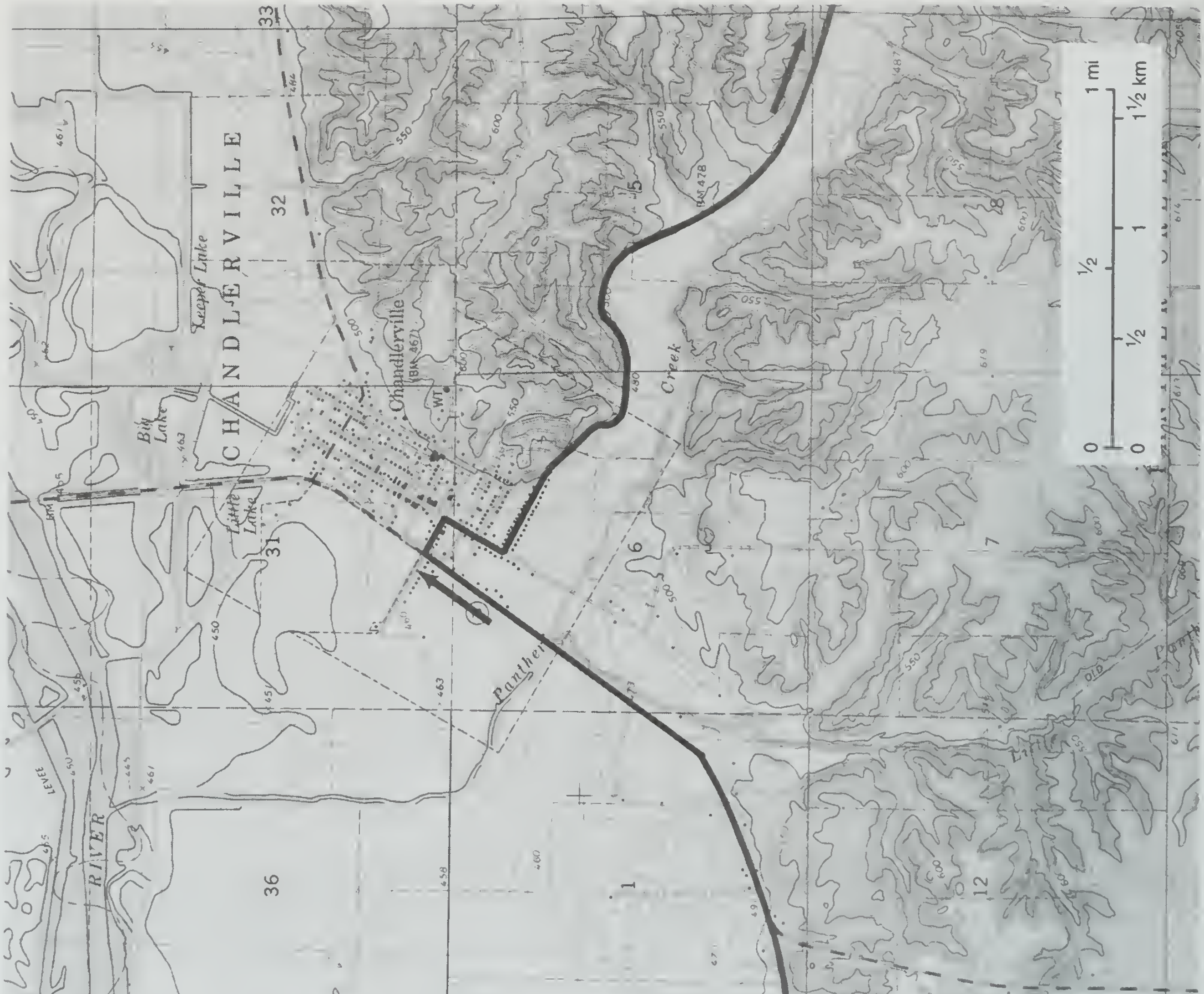
We hope you enjoyed this excursion and found the geology of the area around Beardstown to be interesting and educational. Have a safe journey home! Join us in Hoopeston on May 18, 1996, for more exciting and fun-filled adventures.

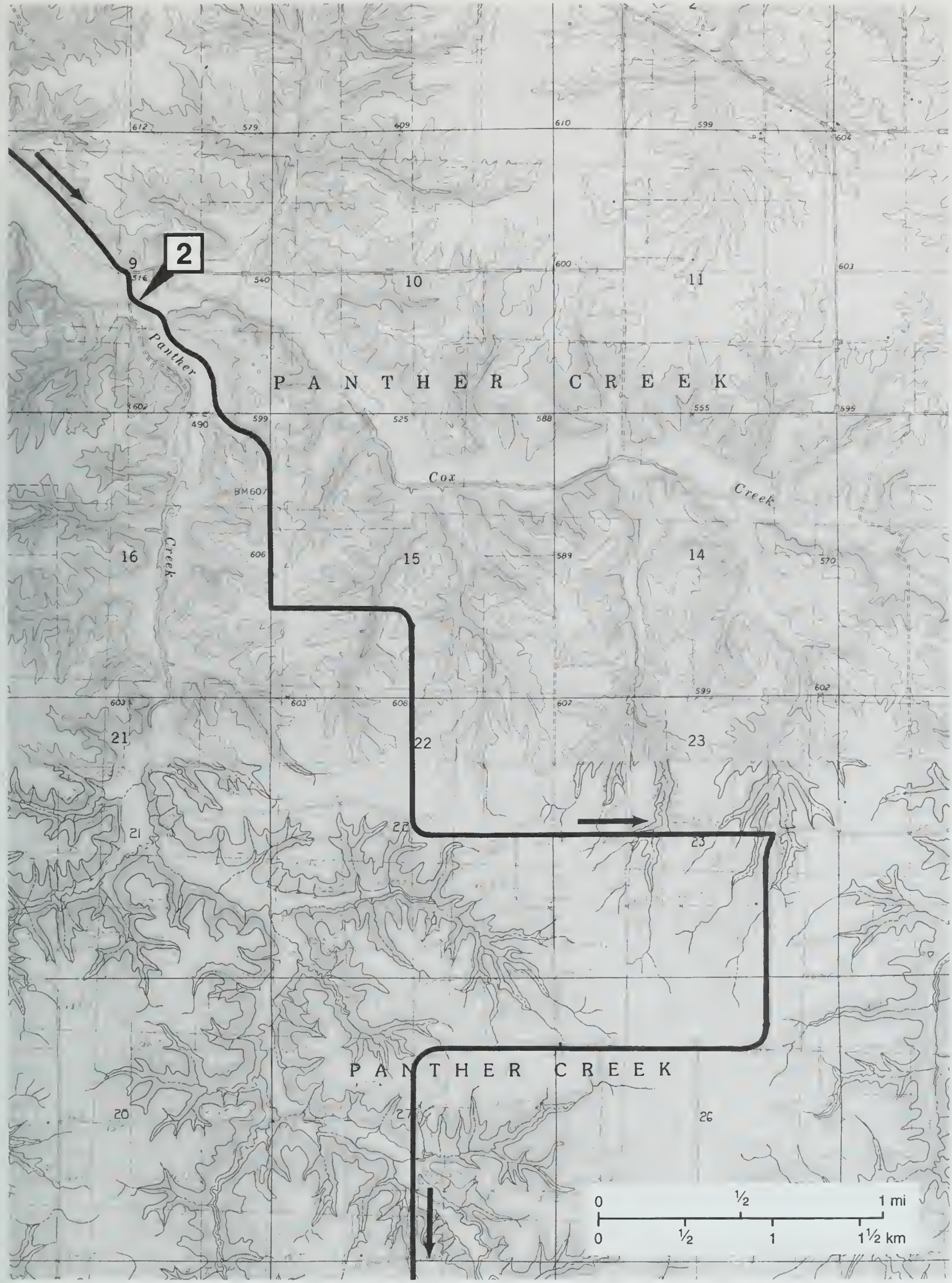

START
1
BEARDSTOWN
B E A R D S T O W N
B L U F F
SANGAMON
ILLINOIS
Hager Slough
Lost Creek
Muscooten Bay
Wood
Meyers Pond
Boat Ramp
Pumping Sta
Oak Grove Cem
Oetgen Cem
Radio Tower
Drawbridge
Elmore Slough
Mile 90
Pumping Station
Lake
Radio Towers
High Sch
Lincoln Sch
Washington Sch
BURLINGTON
0 1/2 1 mi
0 1/2 1 1 1/2 km

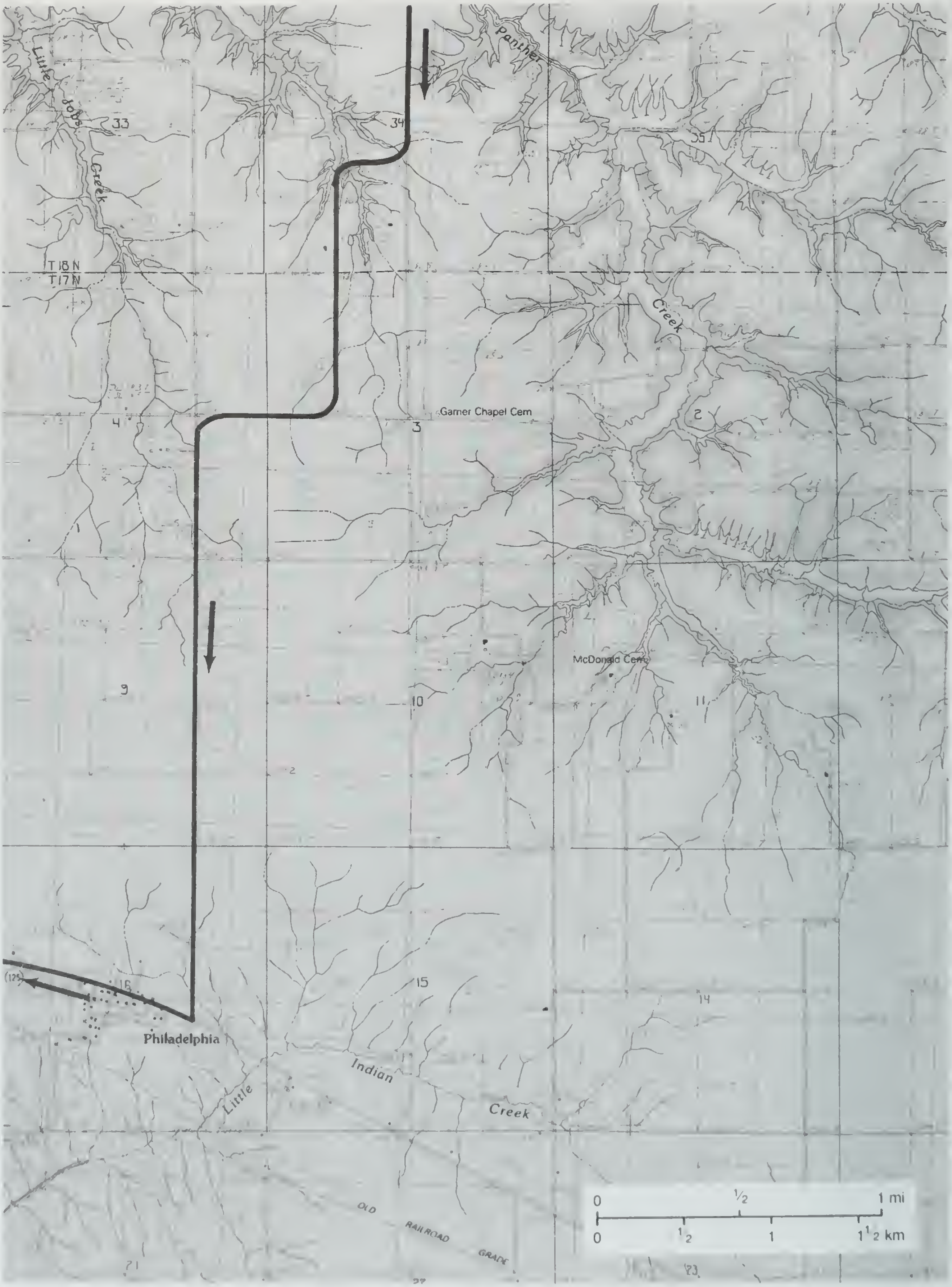


BLUFF SPRINGS
Clear Lake
Clear Lake
Hager Cem
Kuhlman
DITCH
Beard Cem
Lost
Creek
0 1/2 1 mi
0 1/2 1 1 1/2 km


SANGAMON VALLEY
SANGAMON
Indian Run
DITCH
SCHAAD
MAIN
Hager Cem
Carr Cem
0 1/2 1 mi
0 1/2 1 1½ km

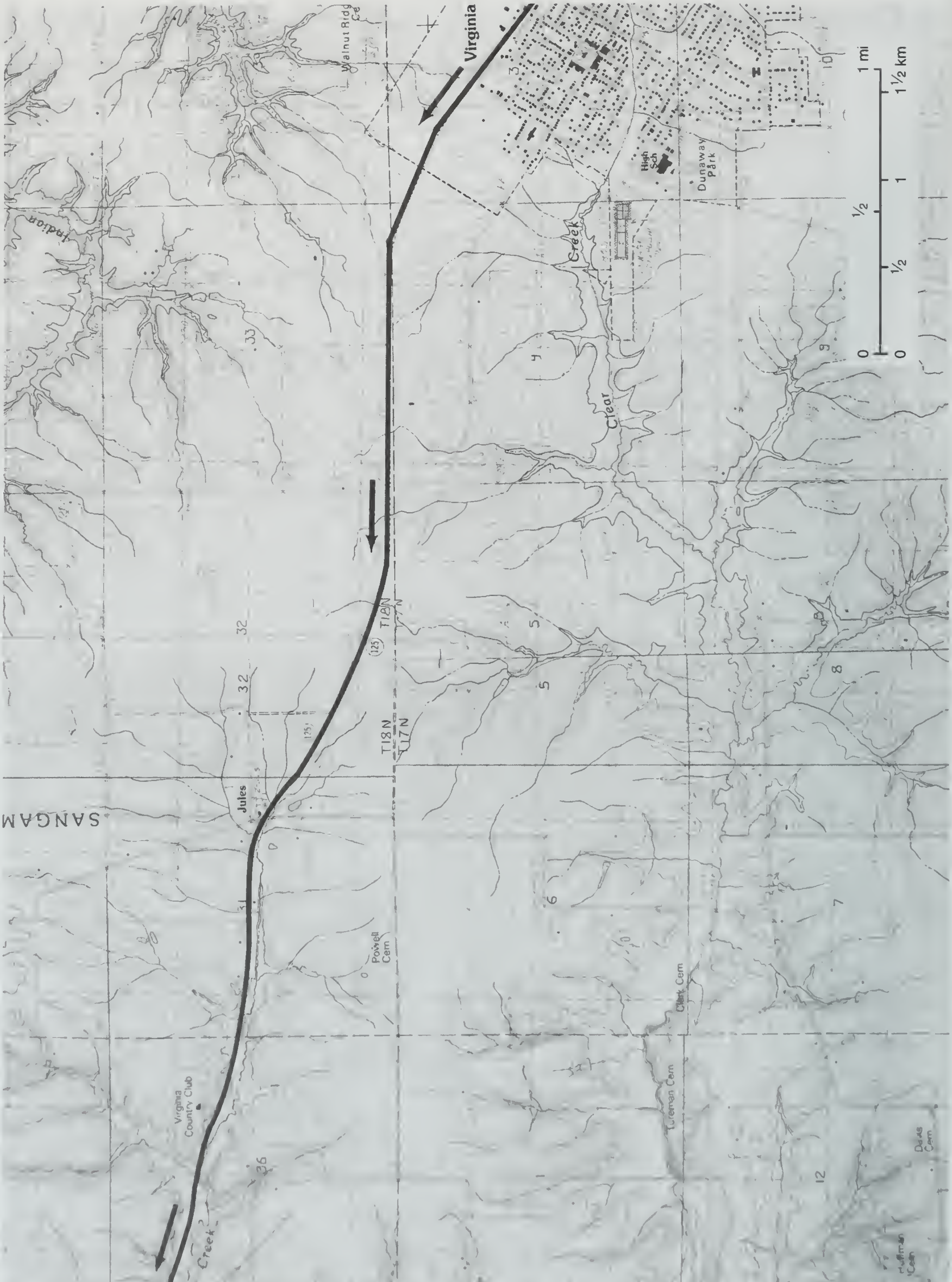

CHANDLERVILLE
Chandlerville
SANGAMON
RIVER
LEVEE
Big Lake
Little Lake
Panther
Creek
VALLEY
Maximillian
Hollow
31
32
33
34
35
36
1
2
3
5
6
7
8
11
12
0 1/2 1 mi
0 1/2 1 1/2 km

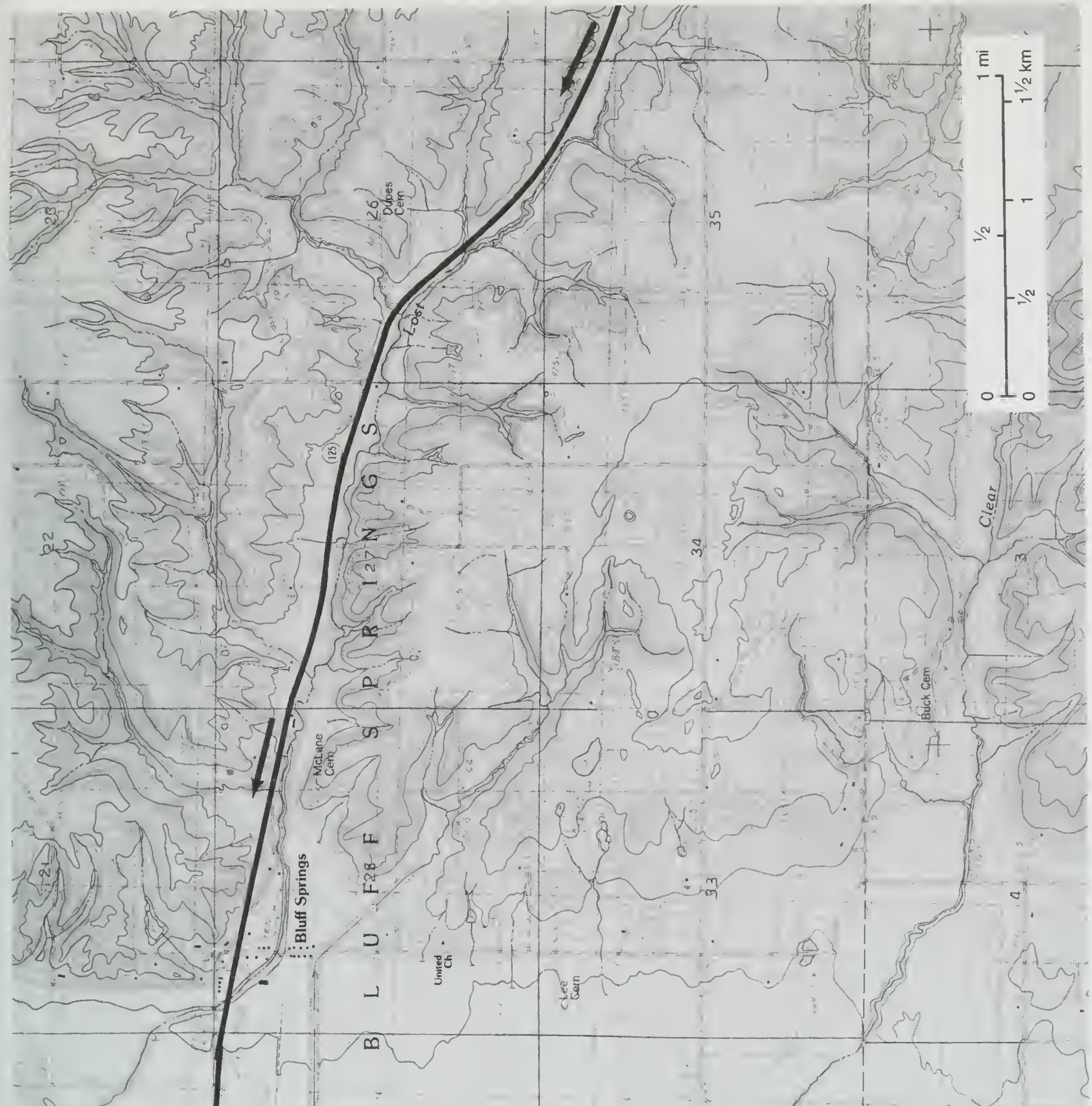

2
P A N T H E R C R E E K
Panther
Creek
Cox
Creek
BM 607
9
10
11
14
15
16
21
22
23
20
26
27
612
579
609
610
599
604
516
540
600
603
602
490
599
525
588
555
595
606
589
570
603
603
606
607
599
602
P A N T H E R C R E E K
0
½
1 mi
0
½
1
1½ km



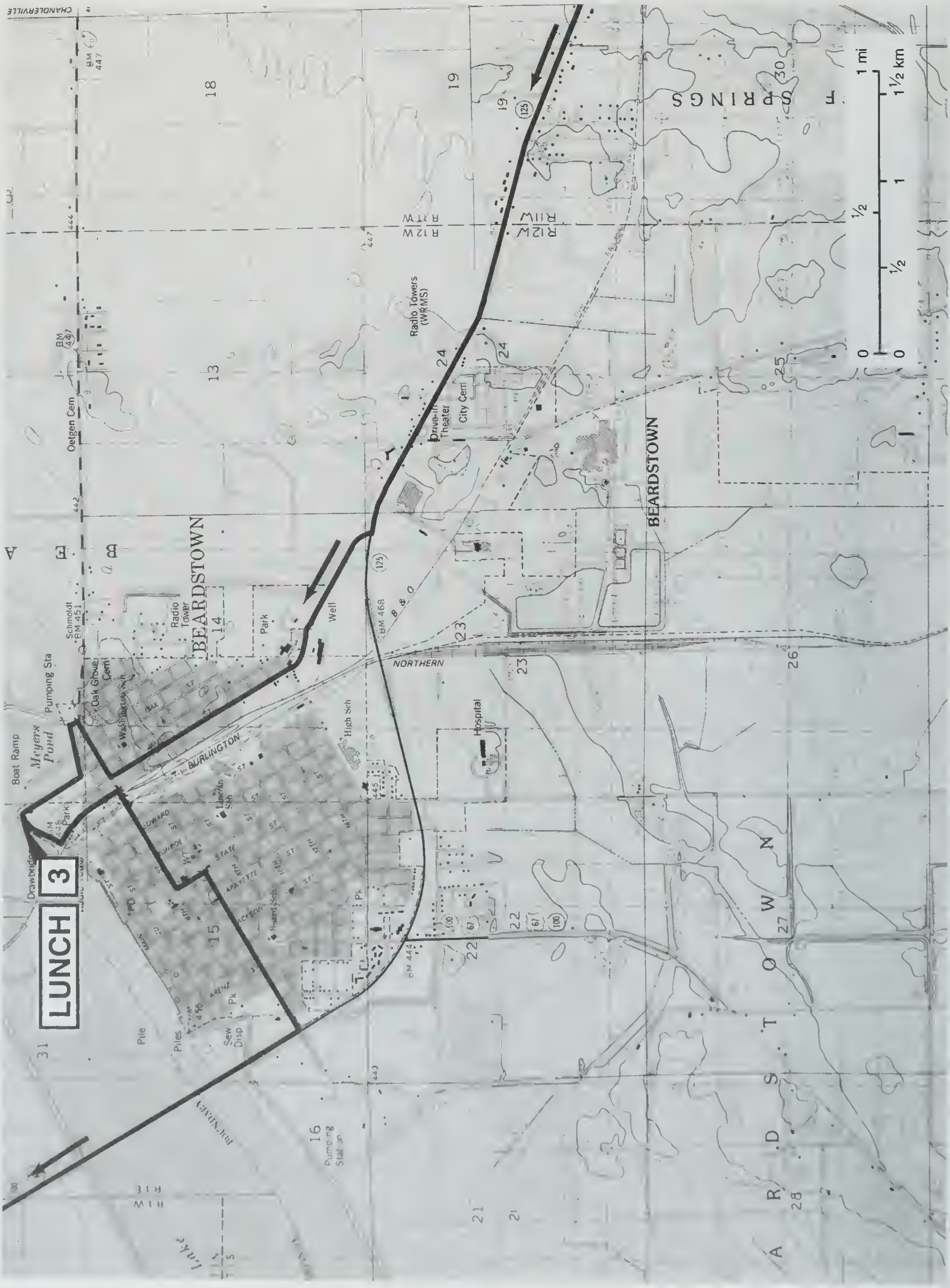
Little Jobs Creek
Panther Creek
33
34
35
T18N
T17N
Garner Chapel Cem
4
3
2
McDonald Cem
9
10
11
(125)
16
15
14
Philadelphia
Little Indian Creek
OLD RAILROAD GRADE
0 1/2 1 mi
0 1/2 1 1 1/2 km

Virginia
Hopkins Cem
Robertson Cem
Springer Cem
Burlingame
RAILROAD
GRADE
13 OLD
125
0
1/2
1 mi
1 1/2 km

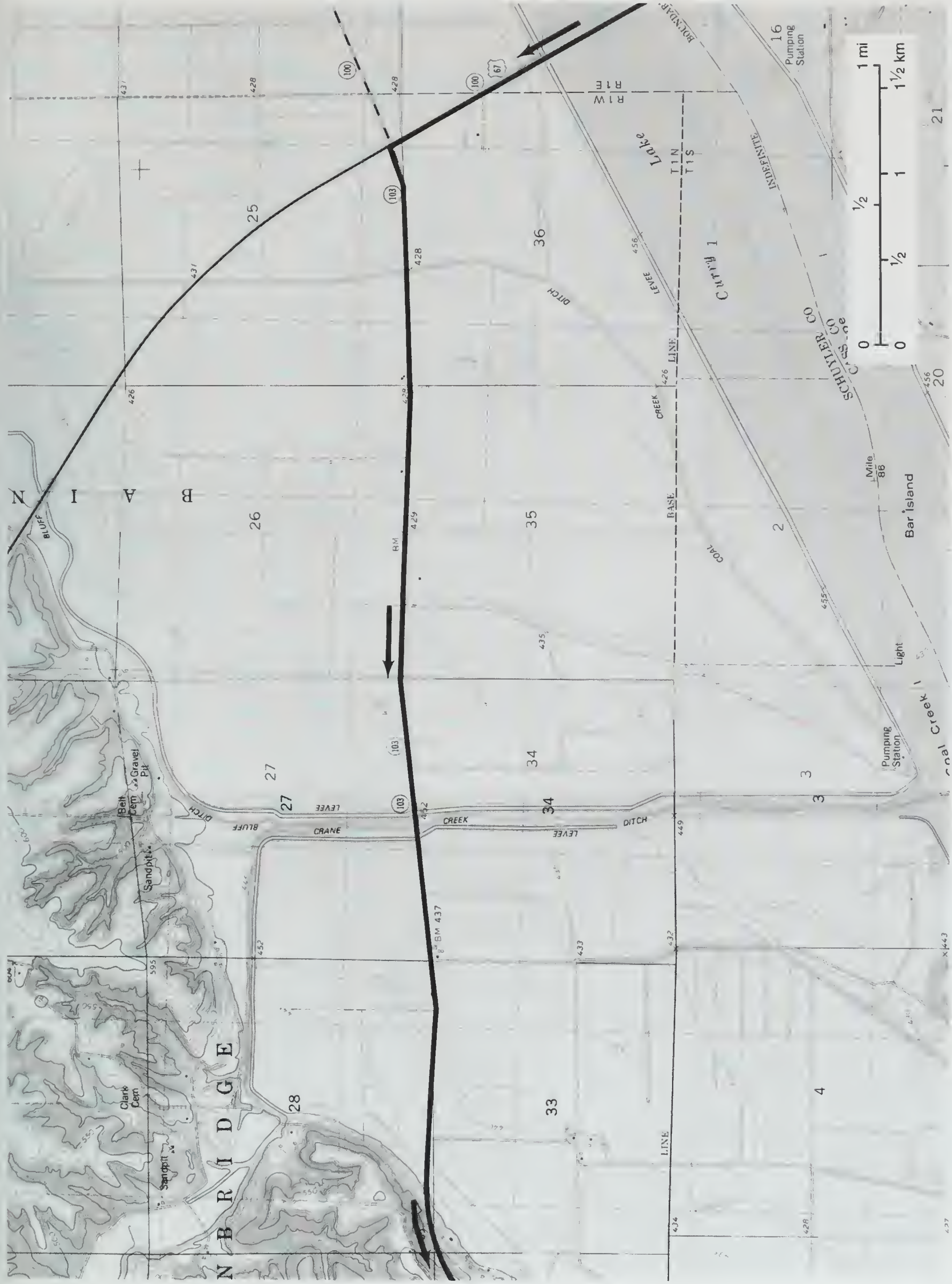

Virginia
Walnut Ridge Cem
Indian
Creek
Clear
High Sch
Dunaway Park
T18N
T17N
125
Jules
Powell Cem
Clark Cem
Tureman Cem
Virginia Country Club
Creek
0
1/2
1 mi
1
1 1/2 km



Bluff Springs
B L U F F S P R I N G S
McLane Cem
Dupes Cem
United Ch
Lee Cem
Buck Cem
Lost
Clear
125
T18N
T17N
19
20
21
22
23
26
27
28
29
30
31
32
33
34
35
3
4
5
6
0 1/2 1 mi
0 1/2 1 1 1/2 km

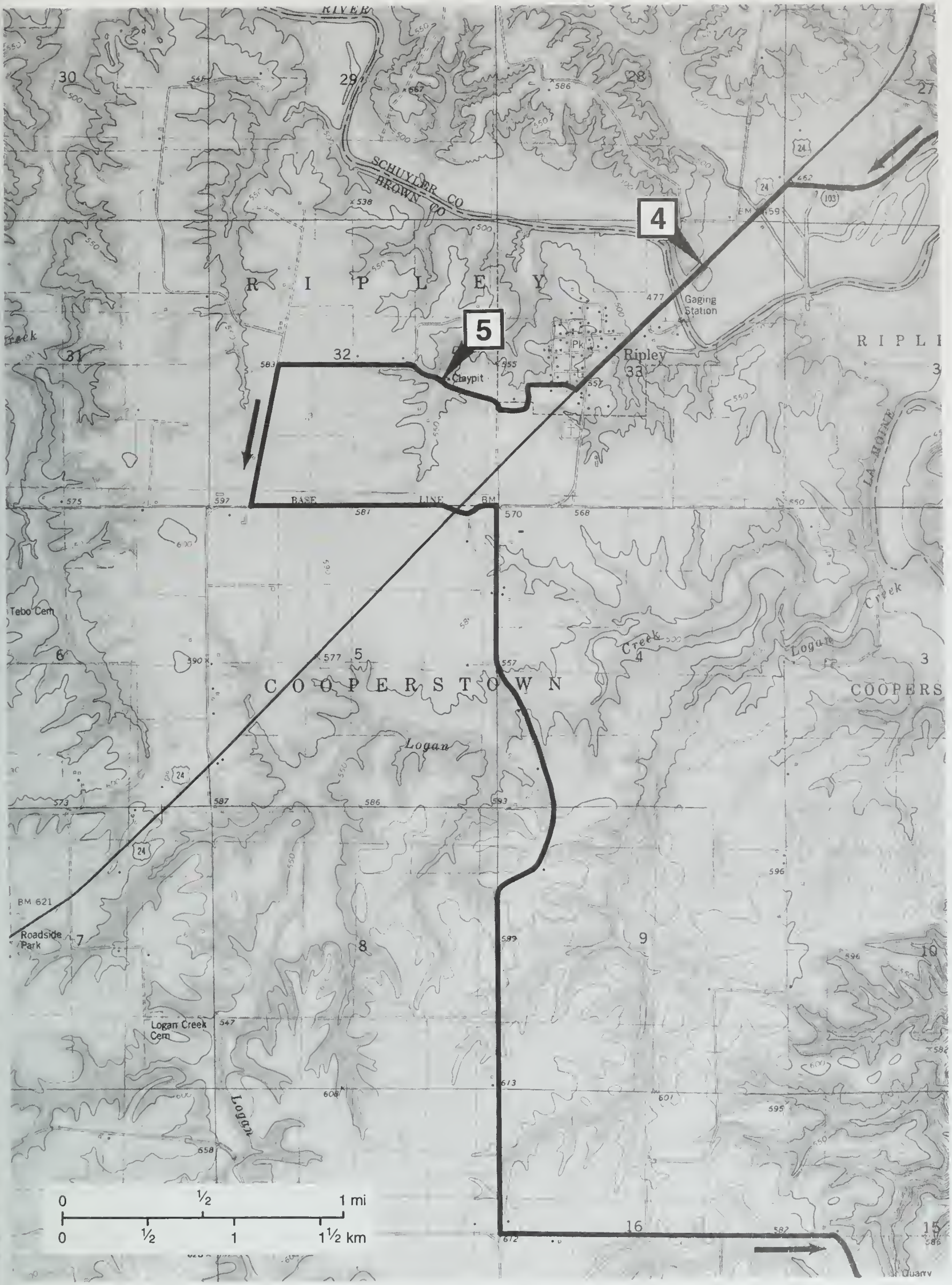


LUNCH
3
Drawbridge
Boat Ramp
Meyers Pond
Pumping Sta
Oak Grove Cem
Park
Radio Tower
BEARDSTOWN
Well
BURLINGTON
NORTHERN
High Sch
Hospital
Drive-in Theater
City Cem
Radio Towers (WRMS)
Oetgen Cem
Schmoldt
Sew Disp
Piles
Pile
Pumping Station
BEARDSTOWN
R12W
R11W
CHANDLERVILLE
S P R I N G S
A R D S T O W N
0
1/2
1 mi
1
1 1/2 km

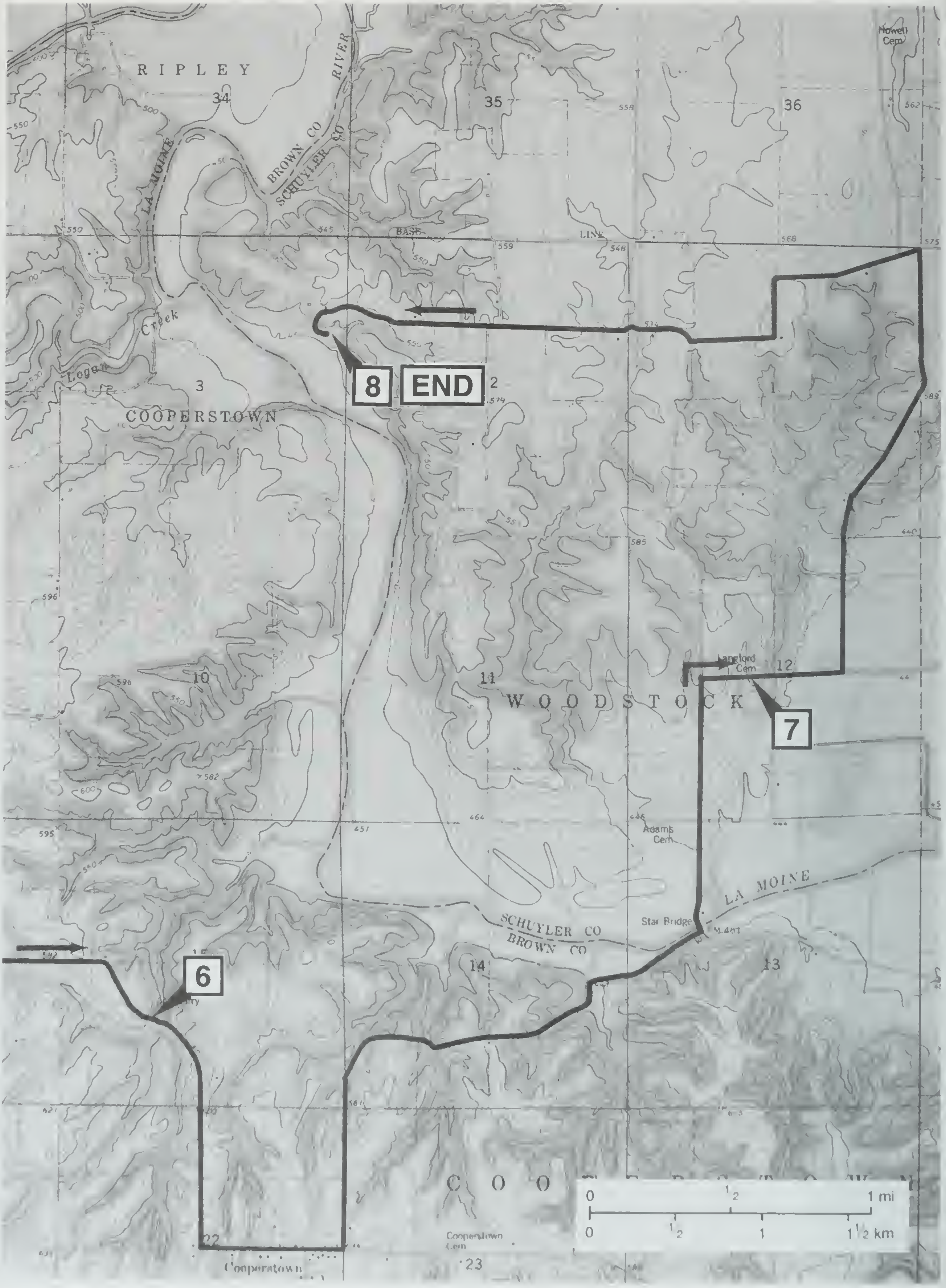


BRIDGE
BAIN
BLUFF
CRANE CREEK DITCH
LEVEE
BLUFF DITCH
Belt Cem
Gravel Pit
Sandpit
Clark Cem
BM 437
BM 429
Lake
Curry
DITCH
LEVEE
COAL CREEK
BASE LINE
T1N
T1S
R1W
R1E
BOUNDARY
INDEFINITE
SCHUYLER CO
CASS CO
Mile 86
Bar Island
Light
Pumping Station
Coal Creek
0
1/2
1 mi
1
1 1/2 km

W O O D S T O C K
Town
Crane
Creek
Jackson Cem
Sandpit
Stephens Cem
Serat Cem
Jonte Cem
Sugar Grove
BM 551
103
Radio Tower
Davis Cem
Howell Cem
Kroche Cem
WT
BASE
LINE
RIVER
BROWN CO
SCHUYLER CO
P L E Y
25
26
27
29
30
31
32
34
35
36
1
2
3
5
6
0
½
1
1 mi
1½ km
Gravel Pit



RIVER
SCHUYLER CO
BROWN CO
R I P L E Y
4
5
Gaging Station
Claypit
Ripley
RIPLE
BASE LINE
C O O P E R S T O W N
COOPERS
Logan
Creek
Logan Creek
LA MOINE
Tebo Cem
Roadside Park
Logan Creek Cem
Quarry
0 ½ 1 mi
0 ½ 1 1½ km


RIPLEY
34
35
36
BROWN CO
SCHUYLER CO
RIVER
LA MOINE
BASE LINE
Logan Creek
3
2
1
8
END
COOPERSTOWN
10
11
12
WOODSTOCK
7
Langford Cem
Adams Cem
LA MOINE
Star Bridge
SCHUYLER CO
BROWN CO
6
14
13
22
23
Cooperstown
Cooperstown Cem
Howell Cem
0
1/2
1 mi
0
1/2
1
1 1/2 km

STOP DESRIPTIONS

STOP 1 Lost Creek Levee System (NW, SE, NW, Sec. 12, T18N, R12W, 3rd P.M., Cass County, Beardstown 7.5-minute Quadrangle [40090A4]).

Lost Creek has a levee on both sides of the creek. From the bridge you can see the levee along the Sangamon River to the northwest. The Lost Creek levee system serves to channel water to the Illinois River from the uplands east of this site. Two levees are necessary to protect against reverse flow from the Illinois River, back to the east, in times of high river stage. In any levee district, a system must be provided to move water from uplands to the river during floods. This can be accomplished either by pumping water up and over the main levees, or by building levees on both sides of tributaries to the main river. At Lost Creek the two levee system is used. Supplementary pump stations exist also, both north and south of this site. Notice that the levee on the south side of Lost Creek is slightly higher than the levee on the north side. The south levee protects the city of Beardstown. The north levee protects mostly farmland and a few houses. More money has been invested, per mile of levee, in protecting the city than has been invested in protecting the farmland.

Floodplains

Many Illinois cities, towns, and villages are situated along rivers. Early settlers depended on streams for drinking water, transportation, and power to run their mills and factories. The floodplains, created by overbank sediments deposited during floods, are some of the most fertile farmlands. The earliest forts, towns, and farms, therefore, were established along rivers.

Runoff

The land area drained by a river is called a drainage basin. Rainfall that reaches the ground is divided into three components: most of it soaks into the ground (infiltration), a portion of it evaporates, and some of it may flow across the ground surface and into streams (runoff). Runoff occurs when the rate of rainfall exceeds the rate at which water can infiltrate the soil. It is affected by many features of the drainage basin, including the permeability of the soil, the vegetation, and the number of streams in the basin. The amount of runoff increases during rainy seasons when the ground becomes saturated, or when the ground is frozen and no moisture can soak into it. As the amount of runoff increases, so does the possibility of flooding. Runoff is measured in two ways: by the stage or height of a river or stream (depth of the water) or by the discharge (volume of water per unit of time). The discharge, the measure commonly used by geologists, can be determined from the stage height at a gauging station if the shape of the river's channel (and therefore the area of its cross section) and the velocity of the river's flow are known.

The layers of decaying humus and natural vegetation of forests and grasslands help reduce runoff by soaking up precipitation. In addition, the roots help increase percolation into the topsoil and subsoil by forming funnels through which water can travel. Closely planted, long rooted crops increase percolation, but widely planted crops, such as corn, and fallow fields increase runoff. The cutting of forests and the plowing of grasslands have increased the proportion of rainfall that runs off the land, thus increasing the probability of floods. The water also carries with it large quantities of the richest topsoil, which muddies the rivers and is ultimately deposited in the Gulf of Mexico.

Runoff and erosion can be decreased by replanting forests and grasslands along the steepest slopes and by creating greenways along the creeks and streams. Terracing, contour plowing, low till or no till planting practices, and a wise choice of crops can reduce runoff and erosion on gentler slopes. Damming gullies reduces runoff by slowing stream velocities and controls erosion upstream by trapping sediment behind the dams. Flood-prevention and erosion-control measures go hand in hand. Preventing soil erosion also aids flood control by reducing the amount of sediment deposited in reservoirs and river channels.

Floods

A flood occurs when the capacity of a stream channel is exceeded by the volume of runoff, and the water spills out of the channel and onto adjacent land, commonly referred to as the floodplain. When the water leaves the channel, its velocity decreases and it loses energy, dropping coarse grained sediments (sand and gravel) out of suspension to create a natural levee along the top of the bank. Farther out on the floodplain, the water moves slowly and deposits fine grained sediments (silt and clay) over large areas. The deposition builds up the level of the floodplain. The floodplain also serves as a storage area for some of the flood water, which is not released until the flood recedes.

When Illinois was first being settled, damages suffered from floods were limited. However, with the increased populations and industrial development along the rivers, flood damage has become a serious economic problem for communities, counties, the state, and the nation.

The Great Flood of 1993

Nine states were declared disaster areas because of this century's worst flooding on the Mississippi, Missouri, Illinois, and adjacent rivers. North and South Dakota, Minnesota, Iowa, Western Illinois, southwestern Wisconsin, Missouri, Nebraska, and Kansas were affected. More than 10.2 million acres were inundated, making for one of the worst farming seasons ever. The rains began in March and continued through the summer. Many areas received 150% to 200% of their average rainfall amounts. Damage was in the billions of dollars. The area was so waterlogged that flood waters were slow to abate. By the next planting season, some of the land was still underwater, and much of it was still too wet to plant crops.

At Beardstown, the flood of 1993 was the second highest on record. The floods of 1943 were a fraction of one foot higher. Downstream of Beardstown, most of the levee districts along the Illinois River suffered the highest flood record in 1993 and many of those levees were overtopped by flood waters.

Flood Control

There are two basic approaches to flood control. One approach is to control the extent of flooding by building dams, reservoirs, levees, and other man-made structures. The other is to control the height of floods by conservation practices designed to hold the water where it falls in the drainage basin (watersheds).

During periods of high flow, a levee confines the river water within a narrow channel. This constriction raises the peak of flood waters upstream and downstream. Once the construction of levees begins, they usually have to be built at all low points along a river system. Furthermore, a system of levees in one drainage district is only as strong as its weakest spot, thus uniform heights and strengths are required to ensure protection for all areas.

Overview of Levee Construction and Failure

The following descriptions are from ISGS Special Report 2 (Chrzastowski, et al. 1994).

Levees are linear, earthen mounds of two general types, depending on what they protect. Agricultural levees protect farmlands; urban levees, generally higher and broader structures, protect cities. Levees along the floodplains in Illinois are primarily agricultural. Beardstown is protected by an urban levee.

Levees are typically constructed of sediments dredged from river channels or excavated from floodplains. Properly compacted clay is ideal for levee construction because it resists erosion and forms a relatively impermeable barrier to the infiltration of flood water. In contrast, sand allows infiltration,

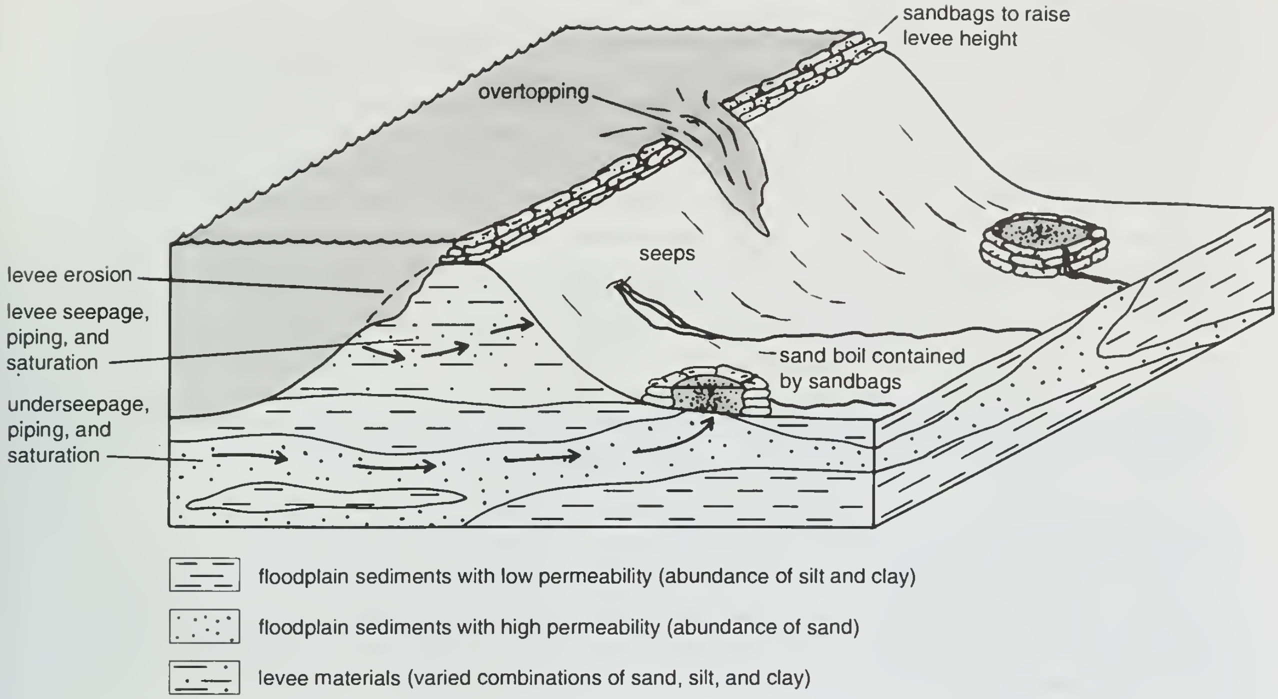


Figure 12 Overtopping, seeps, and piping move water over, through, or under a levee during a flood (after U.S. Army Corps of Engineers 1978).

which can weaken the levee and lead to structural failure. Sand is also easily eroded from the levee. The characteristics of sediments relate to three causes of levee failure (fig. 12).

Surface erosion

The surface of the levee is eroded by flood water lapping against it or by precipitation, as during a heavy rainfall, when drops of water pelt the surface and dislodge particles of sediment.

Levee seepage

The levee is internally weakened as it becomes saturated by water seeping through permeable layers within the levee, or by the process called piping, which occurs when water flows through animal burrows or along the openings made by plant roots, particularly tree roots, and erodes sediment from inside the levee and transports it to the surface (fig. 12).

Underseepage

The ground under the levee is weakened as water moves through porous sand layers beneath the levee and pipes sediment away. Because of the loss of support, the levee may subside or collapse.

A levee can also be weakened by overtopping, which simply means that water flows over the levee. Overtopping is not a type of levee failure, but a case of the flood's height exceeding the design height of the levee. Once overtopping begins, the flow of flood water usually quickly breaches the levee.

Figure 12 illustrates how water moves through, under, and over a levee as it holds back flood water. During the 1993 flood, most levees in Illinois were breached because of overtopping rather than structural weaknesses. In several cases, seepage and underseepage probably contributed to localized weakening and subsidence of levees, which made them more vulnerable to overtopping and breaching.

Levee seeps and sand boils
Flood water on the river side of levees applies pressure to the levees, which are constructed to hold back water for a short time. Because of the unusually long duration of the high water in the flood of 1993, water infiltrated permeable layers within and beneath the levees. The result was seeps piping sand from exposed levee slopes. Sand boils were common on the floodplains adjacent to many levees. They formed where lenses of sand under or within a levee provided a pathway for water to pipe sediment. Unless piping (erosion) of sediment from under or within the levee was halted, the flowing water would quickly sap the levee structure and cause a catastrophic failure. Sand boils are counteracted by building a dike of sandbags around the boil (fig. 12) and allowing water to rise within the ring. The rate of flowing water slows within the ring dike, and the sandbags minimize the loss of sediment by trapping it in place and equalizing the water pressure. Allowing the water to escape over the sandbag dike prevents water pressure from building up elsewhere inside the levee. Sand boils can develop, then cease their activity as changes occur in the flow pathways within the levee. Fine grained materials (silt or clay) transported within the levee may block the flow path and shut off one sand boil while opening a channel for another.

Levee underseepage, piping, and subsidence
Where a large amount of permeable, uncompacted sediment such as sand underlies a levee, the material may become unstable and mobile as it becomes saturated. If saturation occurs, the levee loses support and may sag, forming a low spot in the crest. If underseepage removes sediment beneath the levee, the undermining may bring about a sudden and catastrophic collapse. In either case, flood water can then pour over the subsided or collapsed segment of the levee and quickly erode a deep and wide breach.

Flood Recurrence
The flood recurrence interval is a numerical representation of the likelihood of flooding. The historical record is statistically analyzed and a percent likelihood of occurrence is assigned to a series of discharges. For example, a stream discharge of 1,500 cubic feet per second may have a 10% (1 in 10) chance of occurring in any particular year. Expressed as a recurrence interval, this would be a 10-year flood. A much higher stream discharge may have only a 1% (1 in 100) chance of occurring. This recurrence interval is the so-called 100-year flood. It is important to remember that the recurrence interval does not mean that the flood will occur only once every so many years; it is simply another way of expressing the likelihood for a flood of a particular height to occur during the year.

Recurrence intervals and their associated discharges are used in planning the development of areas prone to flooding and in building structures, such as bridges, dams, and levees, affected by floods. For example, the Illinois Department of Transportation requires that bridges for state and federal highways be designed to allow a 50-year flood discharge to pass through the opening. The Federal Emergency Management Agency (FEMA) uses anticipated flood discharges to delineate flood-prone areas and set flood insurance rates. The FEMA flood insurance rate maps are distributed to libraries and local government agencies for use in planning.

The recurrence intervals and associated discharges are very useful, but they are only as reliable as the data used to calculate them. Most streams in Illinois have been monitored for less than 100 years, so the recurrence intervals for large floods are not well supported by the data available. The effect of this data gap can be minimized by examining floodplain deposits and estimating possible rainfalls and associated runoff.

Effect of Human Activity
As stated earlier, human activity can affect flooding in several ways. Drainage basin alterations, including vegetation removal, paving, and drainage enhancement (ditches and sewers), decrease the capacity of the ground to absorb rainwater and help the runoff reach streams more quickly.

Flood crests rise more rapidly and have higher peak discharges after basin development. River alterations, including channel straightening and levee building, force flood waters to stay within the channel. Floods move downstream more quickly and erode the channel. In addition, with the channel width restricted, stage heights are higher for the same discharge. Areas that haven't been altered may also be affected as flood water reaches them more quickly or as it backs up when it reaches a restricted section of channel. Finally, because they alter the character of a river's floods, human alterations also affect the accuracy of the statistical analyses used to calculate recurrence intervals.

STOP 2a Confluence of Cox and Panther Creeks (Center of NW, NW, SE, Sec. 9, T18N, R9W, 3rd P.M., Cass County, Newmansville 7.5-minute Quadrangle [40090A1]).

Postsettlement alluvium The Site M region was first settled in the mid to late 1820s. The uplands probably were not cultivated extensively at first because of difficulty breaking the strong mats of prairie grass roots in the sod. The uplands were, however, probably grazed by cattle and hogs. In the broad stream valleys, cultivation began during the late 1850s. Sediment that was eroded from the uplands and hillslopes, and redeposited in the major stream valleys is clearly visible in the stream banks at the confluence of Cox and Panther Creek. A unit of light colored alluvium, 1 to 3 feet thick, overlies an older soil profile, which is easily identified by its darker color. The dark color is typical of an organic-rich topsoil. This dark organic layer is the top of the soil that covered the floodplains prior to the advent of land clearing for cultivation and forestry.

STOP 2b Slump along Panther Creek (SE, SW, SE, Sec. 9, T18N, R9W, 3rd P.M., Cass County County, Newmansville 7.5-minute Quadrangle [40090A1]).

This stop illustrates the necessity of integrating regional and site-wide geological information to determine the long-term impacts of decision making on land use.

Geology of hillside The geologic materials in this hillside consist of up to 20 feet of windblown silt (loess) overlying compact sandy, silty diamicton (unsorted, unstratified rock debris composed of many particle sizes) of the Vandalia Till Member of the Glasford Formation (Illinois Episode of glaciation). The loess consists of two units: the underlying and sandier, reddish brown Roxana Silt and the overlying and siltier, light brown Peoria Loess.

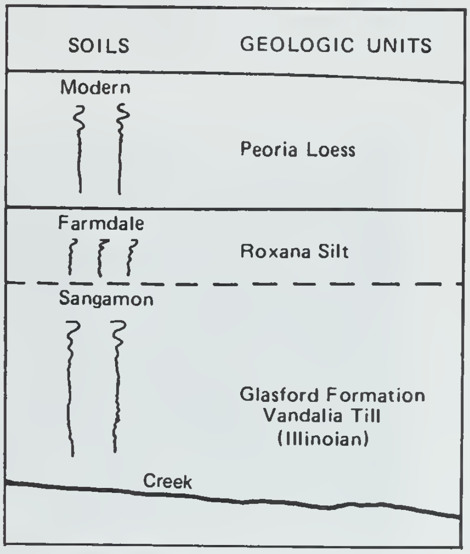


Figure 13 Generalized Quaternary geologic units and soils at Site M.

The slump A large, complex landslide (classified as an earth slump; figs. 13, 14, 15) dominates the hillside. Several typical characteristics of an earth slump are present: (1) a steep scarp at the top, (2) a hummocky surface of disturbed ground consisting of blocks of slumped material below the scarp, (3) tension cracks between some of the blocks (several cracks are large enough to cause injury to unwary walkers, and (4) small wetland areas on the hummocky ground where cattails are growing, a sure sign that some individual slump blocks have rotated and tilted slightly backward, causing rainwater to pond on their surfaces.

If loess is well drained and dry, it will stand in nearly vertical slopes. When saturated, loess is unstable and highly prone to slumping. Thick loess on a hillside, even when it is

covered with grass, can be easily destabilized by excess moisture. In addition, if this hillside was grazed by livestock in past years, the animals' movements over the slope could have helped destabilize it.

Changes in the hillside in the past 60 years Air photos taken in 1938 and 1994 (figs. 16, 17) show some interesting contrasts and changes in the landscape between 1938 and 1994 and allow some insight into possible causes of the slump.

The 1938 air photo shows the hillside and adjacent upland had few trees and may have been used as pasture for the grazing of livestock. The absence of trees, with their deep root systems to take up moisture and help anchor soil in place, may have been an initial contributing factor to the failure of this hillslope.

In the 1938 photo, the road appears to be in good condition. Apparently, it was constructed near the base of the slope, with a narrow strip of gently sloping ground between it and Panther Creek. Although traffic on the road was probably light, construction of the road may have removed some earth materials from the base of the slope, thereby oversteepening it and providing some impetus for slope destabilization.

The 1994 air photo shows that slumping in the hillside was well underway when the photo was taken, and that it probably occurred during at least two different episodes. The most recent episode of slumping resulted in the fresh arc-shaped scarps (the same as those exposed a this stop) toward the southeast corner of the slump area. Larger, older, tree-covered arc-shaped slumps occur immediately northwest of the fresher scarps. In addition, the south side of the newer scarps can be traced on the surface downslope to the creek. The extension of the slump to the creek on the north side can also be seen in the photo, although it is slightly less obvious.

Comparison of other features In addition to the multiple slumping episodes that occurred on the hillslope between 1938 and 1994, other features of interest at this site are the creek meanders, which can be seen near the short north-south segment of the road and east of what is now the slumped area. The small semicircular meander at the corner of the north-south part of the road no longer exists in the 1994 photo, but its trace can still be seen in the plowed field. Although the configuration of the creek at the base of the slump does not appear to have changed much from 1938 to 1994, examination of the ground surface suggests that the toe of the slump has displaced the creek toward the northeast, causing the stream to actively erode the opposite creek bank, undercut the trees, and expose the sediments.

Figure 14 Slump feature along Panther Creek at stop 2.

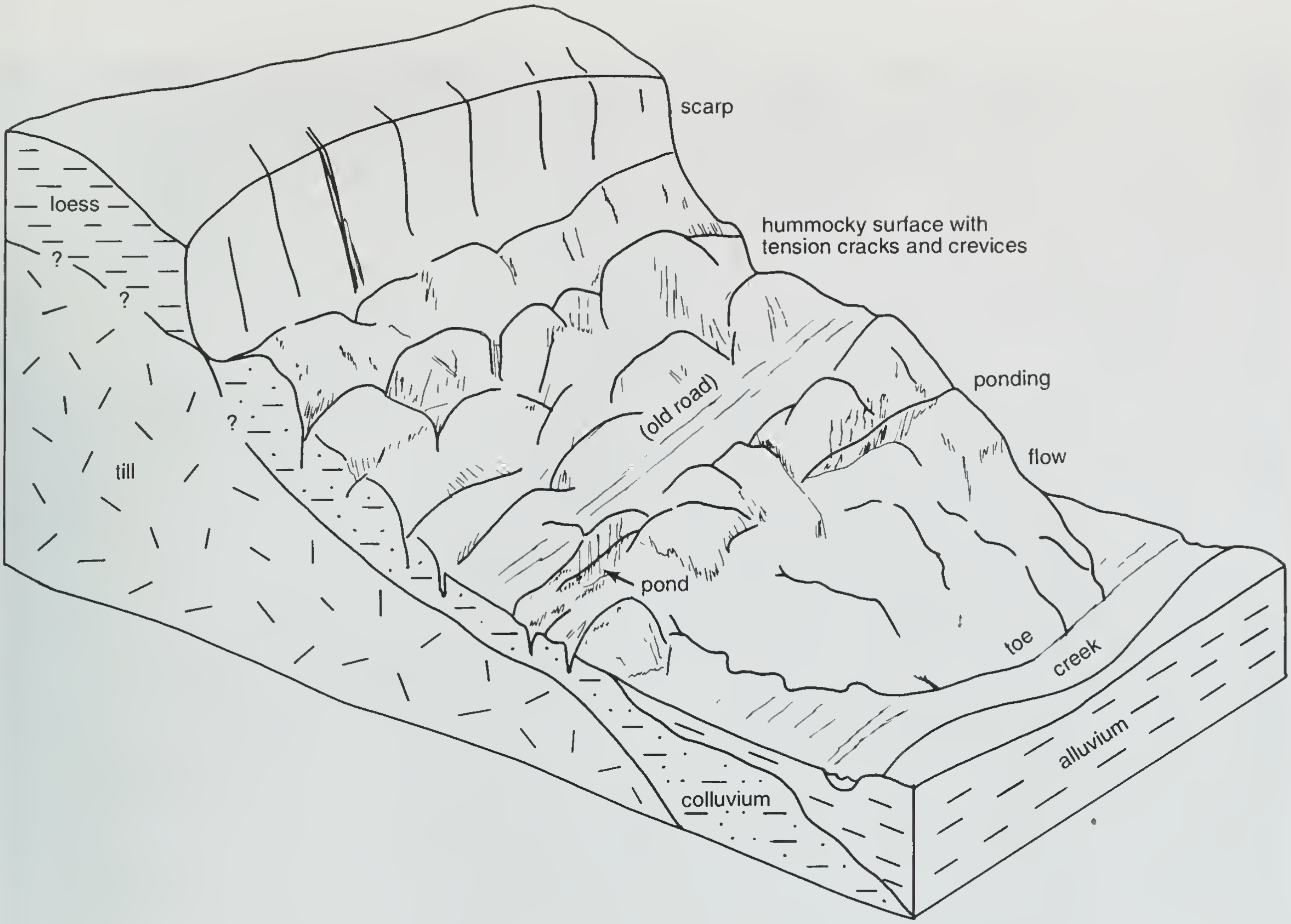


Figure 15 Schematic diagram illustrating some features found in the slump area at stop 2. A steep scarp with nearly vertical walls has formed in loess. Below is a hummocky surface with tension cracks and crevices, suggesting the material is gradually moving down slope. The remains of an old compacted roadbed probably helps produce a somewhat more coherent surface in that vicinity. Ponding of water at the back of some slump blocks has occurred. At the toe of the slump, the material is moving toward the creek. Stream erosion at the toe creates instability.

Geologic Description of Floodplain Sediments

Top of stream bank exposure

Colluvium and alluvium *(creep and slopewash deposits; stream deposits)*	
Silt (reworked and redeposited reddish brown Roxana Silt and light brown Peoria Loess); presettlement soil buried 12 to 16 inches below land surface at this location	60 inches
Pebble line, mostly reprecipitated carbonates	1 inch
Glacial deposits	
Diamicton, loamy, yellowish brown, abundant coal fragments	12 inches
Diamicton, silty, dark brown to grayish brown	14 inches
***Lacustrine** (lake) **deposits** (low-energy, transitional to boggy environment)*	
Sand, very fine, well sorted; brownish to grayish yellow	3–4 inches
Silt, light brownish gray	24–30 inches
Silt, dark gray, jointed, oxidized along joints	2–4 inches
Silt, black, organic, highly contorted	4–8 inches
Silt, gray, exposed to unknown depth below creek level	

Figure 16 1938 air photo of area surrounding stop 2 at Site M. Compare this photo with the 1994 air photo.

Figure 17 1994 air photo of area surrounding stop 2 at Site M. The slump feature is easily recognized. Compare this photo with the 1938 air photo.

Figure 18 Old iron railroad drawbridge across the Illinois River is raised, allowing a barge to pass beneath (photo by Wayne T. Frankie).

These deposits indicate that prior to the advance of Illinois Episode glaciers, this low area on the floodplain was probably occupied several times by small lakes of uncertain extent. The silts and well-sorted sand suggest such low-energy depositional environments in which fine grained sediments such as silt settle out. However, at one point the lake was transitional to a boggy environment, as evidenced by the black organic silt. How this unit became contorted is a matter for speculation. A possibility is that the layer of organic-rich silt was frozen when a glacier approached near enough to disturb and contort the frozen sediment. Glaciers advanced into the area and deposited the diamictons. Following many thousands of years of erosion, the loess was deposited, and the landscape began to assume its present form. Reworking (erosion and deposition) of the Peoria Loess and Roxana Silt occurred during the last 10,000 years or so as the loess periodically slumped downslope and was picked up and reworked by stream action.

STOP 3 Beardstown Levee and LUNCH (NE, SE, SE, Sec. 10, T18N, R12W, 3rd P.M., Cass County, Beardstown 7.5-minute Quadrangle [40090A4]).

The top of the Beardstown levee offers a good view of the Illinois and Sangamon Rivers, Muscooten Bay, and Meyers Pond (fig. 18). Compare the topography of this area with the route map on page 31 of the guide book. The landscape has significantly changed because of the infilling of Muscooten Bay and Meyers Pond by sediment. Also notice along the Beardstown levee the development of the channel bar, which has cut off any large boat traffic into Muscooten Bay.

Rechannelization of rivers, like that of the Sangamon River, shortens and straightens the channel. This speeds up the river's flow and thus lowers flood stages upstream. However, if the gradient of the river is increased (same drop in elevation over a shorter distance), the river will reestablish equilibrium by increasing headward erosion. This leads to increased sedimentation near the mouth of the river.

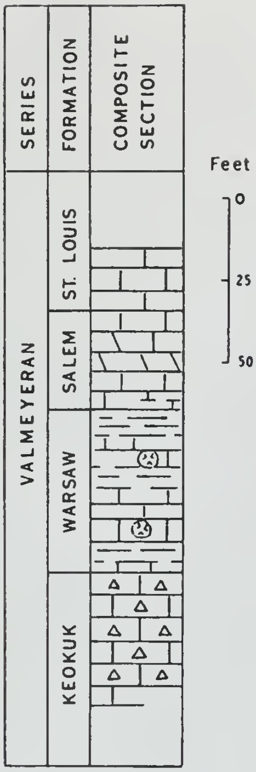


Figure 19 Composite section of Mississippian strata in the field trip area.

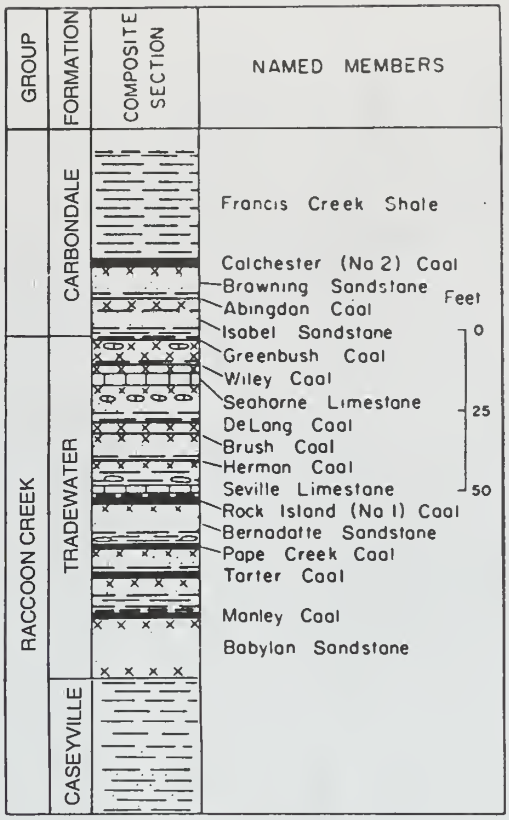


Figure 20 Composite section of Pennsylvanian strata in the field trip area (modified from Reinertsen 1964).

STOP 4 Roadcut northeast of Ripley (SE, NW, NE, Sec. 33, T1N, R2W, 4th P.M., Schuyler County, Ripley 7.5-minute Quadrangle [40090A6]).

A major unconformity marks the Mississippian-Pennsylvanian boundary over much of Illinois (and other parts of the North American continent). This unconformity is well exposed in the roadcut. Prior to the earliest deposition of Pennsylvanian strata in this area (and elsewhere in Illinois), erosion created channels, valleys, and sinkholes in the middle and upper Mississippian strata. During this early period of erosion, western Illinois was a rugged upland that contained wide relatively flat areas bordered and dissected by steep-sided valleys.

During early Pennsylvanian time, this area in western Illinois was topographically higher than the southern parts of the Illinois Basin, and thus continued to be eroded. Erosion led to the removal of all of the Chesterian Series (upper Mississippian) and the underlying Ste. Genevieve Limestone, which have a combined thickness of more than 800 feet thick in southern Illinois. In this part of western Illinois, the lower Pennsylvanian rocks rest unconformably on rocks of middle Mississippian age, including the Salem Limestone as seen in this cut, and elsewhere on the St. Louis (above the Salem) or the Warsaw and Keokuk Formations (below the Salem; fig. 19).

In west-central Illinois, lower Pennsylvanian strata below the Colchester Coal include the Tradewater and Caseyville Formations of the Raccoon Creek Group (fig. 20). The thickness of these rock units increases from less than 1 meter (3.3 feet) in western Brown County to more than 10 meters (33 feet) in eastern Schuyler County. This trend was, however, modified locally by the irregular

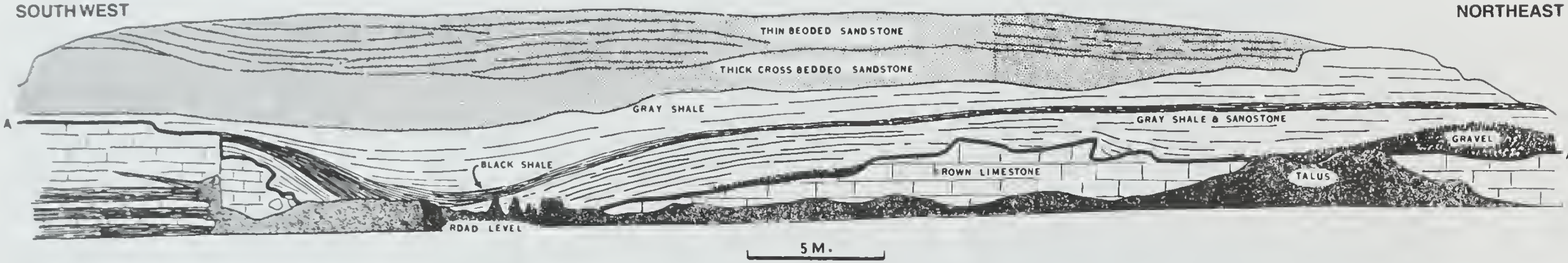


Figure 21 Drawing of a channel eroded in the Salem (Mississippian) Limestone and filled with lower Pennsylvanian sediments. Line A–A′ marks the Mississippian–Pennsylvanian unconformity. Roadcut at stop 4, northeast of Ripley (modified from Leary 1994 .

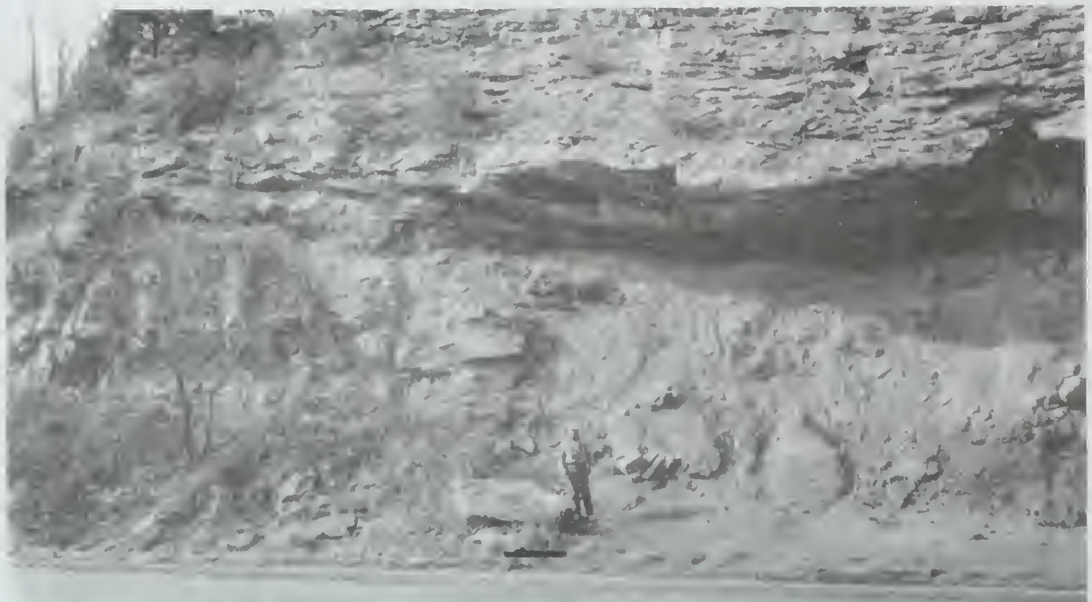


Figure 22 View of northwest roadcut (stop 4), showing lower Pennsylvanian Babylon Sandstone overlying gray and black shales filling unconformity in Mississippian Salem Limestone (photo by Russ Jacobson).

Figure 23 View of southeast roadcut (stop 4) showing unconformity between the lower Pennsylvanian and middle Mississippian strata. Russ Jacobson is standing at the base of lower Pennsylvanian shales that fill this channel (photo by Wayne T. Frankie).

surface on which Pennsylvanian sedimentation took place. These deposits were laid down in channels, valleys, and sinkholes that developed in middle Mississippian Limestones from the St. Louis to Keokuk. These early Pennsylvanian deposits are quite discontinuous and variable in their lithology and thickness. Shales, channel and transgressive sands, basal conglomerates of weathered Mississippian rock, and pockets of clay, shale, and coal may be seen at outcrops. Examples of these lithologies can be seen at this and the next stop.

At this stop (figs. 21, 22, 23) an erosional unconformity was created by a channel that cuts into the Salem Limestone. The channel is about 5 meters (15 feet) deep and filled with shale and sandstone that has thin carbonaceous partings. A thin, but distinctive black shale (containing a limited marine fauna and representing the initial invasion of marine conditions across the entire area exposed in this cut) is present in the middle of the sediments filling the channel. At the northeast end of the channel (fig. 18) is a small subsidiary channel that contains, at its base, a distinctive bed of chert pebbles (a basal conglomerate), derived from erosion of local chert-bearing Mississippian limestone (most likely from the St. Louis; fig 24).

Once the channel depression was filled, the sea retreated (transgressed) and deltas advanced (prograded) into the area depositing the massive, crossbedded sandstone (Babylon Sandstone of the Tradewater Formation) near the top of this cut. Overlying this sandstone is a claystone and a partially eroded coal, possibly the Pope Creek. Remember this coal when we go to the next stop, where we will examine a portion of the Raccoon Creek Group from the Pope Creek Coal up to just under the Colchester Coal (fig. 20).

The Pennsylvanian shales, siltstones, and sandstones filling the erosional channels in the Salem Limestone contain plant remains, including stems, leaves, and some seed pods. Along the La Moine River valley a few miles from this stop, similar sediments deposited in an erosional channel within the Salem Limestone contain some of the earliest known plants found in the Illinois Basin (Leary 1974, 1977). The plants and rocks found in this area of the basin may also be of very early Pennsylvanian age. Thus, this site (and others nearby) gives us a glimpse into conditions and life in early Pennsylvanian times.

Figure 24 Lag conglomerate of chert from weathered Mississippian strata filling channel at stop 4 (photo by Wayne T. Frankie).

The Salem Limestone is predominantly a brown to light brownish gray limestone, dolomitic limestone, or dolomite. This limestone or dolomitic limestone is fine grained (dense), and may be argillaceous (containing clay-size particles), silty or even sandy; it occurs in irregular thin to massive beds. This rock type or facies of the Salem may give way locally to a light gray or greenish gray dolomitic siltstone or dolomitic sandy shale that closely resembles the underlying Warsaw Formation, with which it is in gradational contact, both vertically and laterally.

STOP 5 Clay Pit west of Ripley. Exposures of Pennsylvanian Tradewater Formation (NW, NE, SE, Sec. 32, T1N, R2W, 4th P.M., Brown County, Ripley 7.5-minute Quadrangle [40090A6]).

The strata exposed at this stop belong to the lower Pennsylvanian Tradewater Formation of the Raccoon Creek Group (fig. 25). The rock succession reaches from the shale and underclay below the Pope Creek Coal to the Seahorne Limestone near the base of the Colchester Coal of the Carbondale Formation (fig. 20). The Pope Creek Coal is laterally equivalent to the thin coal near the top of Stop 4.

As noted earlier, in this part of western Illinois the thickness of the Pennsylvanian section between the Colchester Coal (base of the Carbondale Formation) and the Babylon Sandstone (base of the Tradewater Formation) is greatly reduced (fig. 20). At this stop, the De long, Brush, and Herman

Figure 25 View of exposure of Pennsylvanian-age Cheltenham Clay at stop 5 (photo by Wayne T. Frankie).

Coals, Seville Limestone, and Rock Island Coal are not present. Within this reduced interval instead is a thick deposit of claystone.

The abundant claystone commonly found in this thinned Pennsylvanian interval of the Tradewater is called the Cheltenham Clay Member by geologists. This complex claystone member results from the thinning of many units and the merging of several claystone units normally found beneath the coals missing from this section. This greatly thinned and simplified section is the result of nearly constant exposure of the rocks on the margins of the Illinois Basin. With sedimentation rates greatly reduced, only the residual soil represented by the Cheltenham was left.

The Cheltenham Clay along its crop on the western edges of the Illinois Basin has long been known as a refractory clay. It has been used in making bricks, tile, and various other products such as pottery. The exposures of this clay at Ripley are no exception and this particular pit has been long utilized. Cannon Pottery located just east of here still uses the Cheltenham Clay for making several clay products.

Composite Outcrop Description

Seahorne limestone, knobby, lenticular, with marine fossil debris	0–10 inches
Cheltenham clay	6–8 feet
sandstone, clean, quartz arenite	.5–1.5 feet
claystone, gray	2 feet
Pope Creek Coal, weathered	4 inches
underclay	3 feet

Figure 26 Typical selenite gypsum crystals found on the exposed surface of the Cheltenham Clay at stop 5 (photo by Wayne T. Frankie).

The Pope Creek Coal is exposed on the right-hand side of the roadcut on the west side of the creek. The color variations in the Cheltenham Clay appear to be surface features caused by the effects of weathering on clay's varying chemical composition. Gypsum crystals occur on the weathered surfaces of the claystone (fig. 26). The sulfate (SO_4) ions needed to form gypsum is probably derived from weathering of pyrite (FeS_2) and, perhaps, other sulfide minerals in the claystone.

STOP 6 "Cooperstown Creek," Mississippian limestone (SW, NE, SW, Sec. 15, T1S, R2W, 4th P.M., Brown County, Cooperstown 7.5-minute Quadrangle [39090H5]).

Three rock units of middle Mississippian (Valmeyeran) age are exposed in this abandoned quarry and at several exposures along the small stream (figs. 27, 28). A generalized section of the rocks exposed near the bridge (south portion of the creek) is shown in figure 29. The oldest rock unit (geologic formation) exposed is the Warsaw Shale, which is present in the stream bottom and forms the lower part of the stream's sides. Above the Warsaw Shale lies the slightly younger Salem Limestone, which forms the upper part of the side walls of the stream nearer the main road. The lip of the small waterfall is within the Salem. The youngest unit is the St. Louis Limestone, which rests on the Salem. It is only exposed in the small abandoned quarry on the northwest side of the stream.

Several post depositional chemical changes have affected the Mississippian units in this area. Dolomitization has variably affected all three formations. Dolomitization is a process by which a

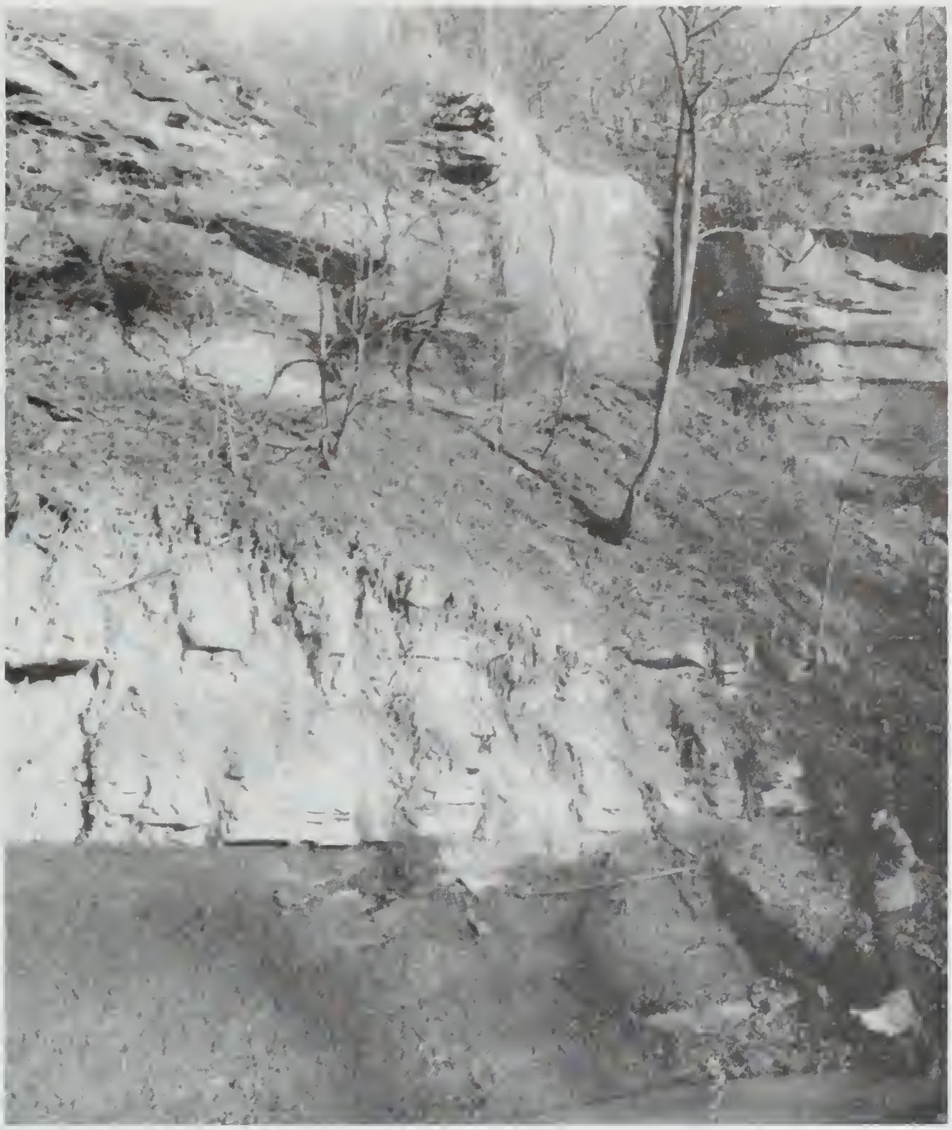


Figure 27 Exposure of typical Salem Limestone that forms bluffs overlying limestones and shales of the Warsaw Formation at stop 6. Geologist Russ Jacobson is standing on the Warsaw shale (photo by Wayne T. Frankie).

calcium carbonate (limestone [$CaCO_3$]) is converted to a calcium-magnesium carbonate (dolomite [$CaMg(CO_3)_2$]). Iron oxide is commonly present, especially in the Salem and Warsaw fossiliferous limestones, and it is probably precipitated later from water percolating through the rock. Silicification (a process by which silica is either precipitated [formed in an opening], or replaces some other mineral) has resulted in the formation of geodes in the Warsaw and cherts in some intervals in the St. Louis. (See *Geodes—Small Treasure Vaults in Illinois* at the back of the guidebook).

The middle Mississippian rocks, especially the Salem and St. Louis, are economically important units for this area, as well as for the rest of Illinois. They are an important source of construction aggregates and agricultural lime. In the subsurface, they are important reservoirs for hydrocarbons in the southern part of Illinois.

Warsaw Shale

The Warsaw consists primarily of light to medium gray shale interbedded with finely crystalline, argillaceous, silty dolomite (particularly in the upper part of the rock unit) and light gray to olive gray (sometimes rusty where weathered) fossiliferous limestone. An example of fossiliferous limestone

Figure 28 Exposure of bioclastic limestone in Warsaw Formation at stop 6. Note the limestone lens above and to the left of geologists Rod Norby and Zak Lasemi. This lens quickly pinches out to their right (photo by Wayne T. Frankie).

can be seen best a few hundred yards downstream where it forms the lip of the small waterfall and one or two ledges below. The limestone is fossiliferous with abundant bryozoans and common brachiopods, gastropods, and echinoderm fragments and stems. The shale and argillaceous dolomites are less fossiliferous in this area. Geodes are present, but they are generally uncommon in the upper reaches of the stream. Small, poorly formed geodes are common to abundant in the lower reaches of the stream about 1/2 mile from the bridge.

Depositional Environments of the Warsaw

The Warsaw was deposited during a period when siliciclastic material (mostly silt and clay) was being supplied to the sea from emergent land areas, primarily to the west and north. Abundant animal and plant nutrients associated with these siliciclastics promoted growth of filter-feeding, calcium-carbonate-secreting organisms such as bryozoans and echinoderms. Because large amounts of silt and clay inhibit development of many carbonate-producing organisms, a topographic high on the seafloor was necessary for these organisms to flourish. Where irregular seafloor topography promoted their development, abundant crinoids (an echinoderm) and lacy and twig-like bryozoans were able to baffle the currents and trap fine grained sediments. This action resulted in mound-like, limestone-rich features surrounded by siliciclastic sediments. These mounds were the sites on which bryozoans, echinoderms, and other organisms such as brachiopods and gastropods flourished. Shells and fragments from these organisms were transported by storm and tidal currents and deposited as major components of sand bars, shoals, or channels. Fossiliferous sand bars are represented, at the second substop near another small waterfall, by discontinuous, lenticular bodies consisting of fossil hash and commonly whole fossils, which are difficult to collect except by breaking off a piece from a block or slab. This will be one of the better places to collect fossils. The fossil fragments that form these bioclastic limestones (a term for limestones with fossils as a primary component) are not rounded or sorted (equal grain size). This characteristic indicates that bioclastic limestones of the Warsaw were deposited rapidly (possibly by storm currents) and were not subjected to continuous current agitation.

Salem Limestone

The Salem Limestone overlies the Warsaw and consists of light gray, relatively clean (very little mud), primarily very fine to fine grained, and some medium grained bioclastic limestone. Fossil fragments in the Salem limestones are, for the most part, well rounded and sorted, a characteristic

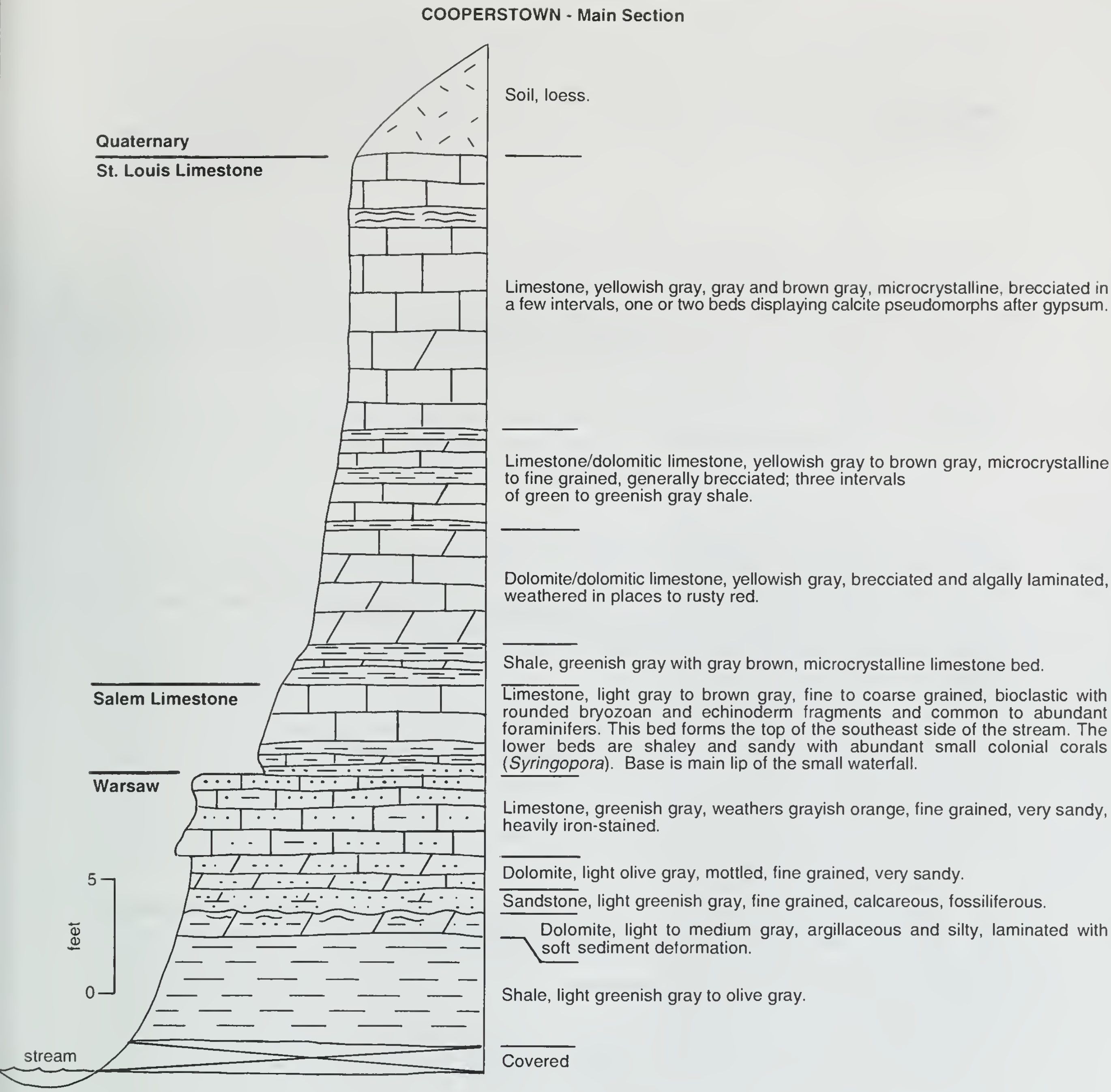


Figure 29 Detailed stratigraphic section of Mississippian rocks exposed along the creek at stop 6, near the bridge.

indicating constant current agitation during deposition. The Salem generally contains small spherical grains called ooids or coated grains. Coated grains are present in some beds in the Salem at this stop, but they are generally too small to be seen with the naked eye. Ooids have concentric layers that are formed by inorganic and organically induced precipitation of calcium carbonates around preexisting grains. Rocks made out of ooids are called oolitic limestones. Oolitic limestones indicate precipitation in a high energy carbonate environment that has intense wave and tidal current activities. Another characteristic of the Salem in this area is the abundant occurrences of small single-celled animals, called Foraminifera or forams, which secreted a calcium carbonate shell. These forams are, however, also too small to be seen by the naked eye, but they can be seen

COOPERSTOWN - Farthest downstream section

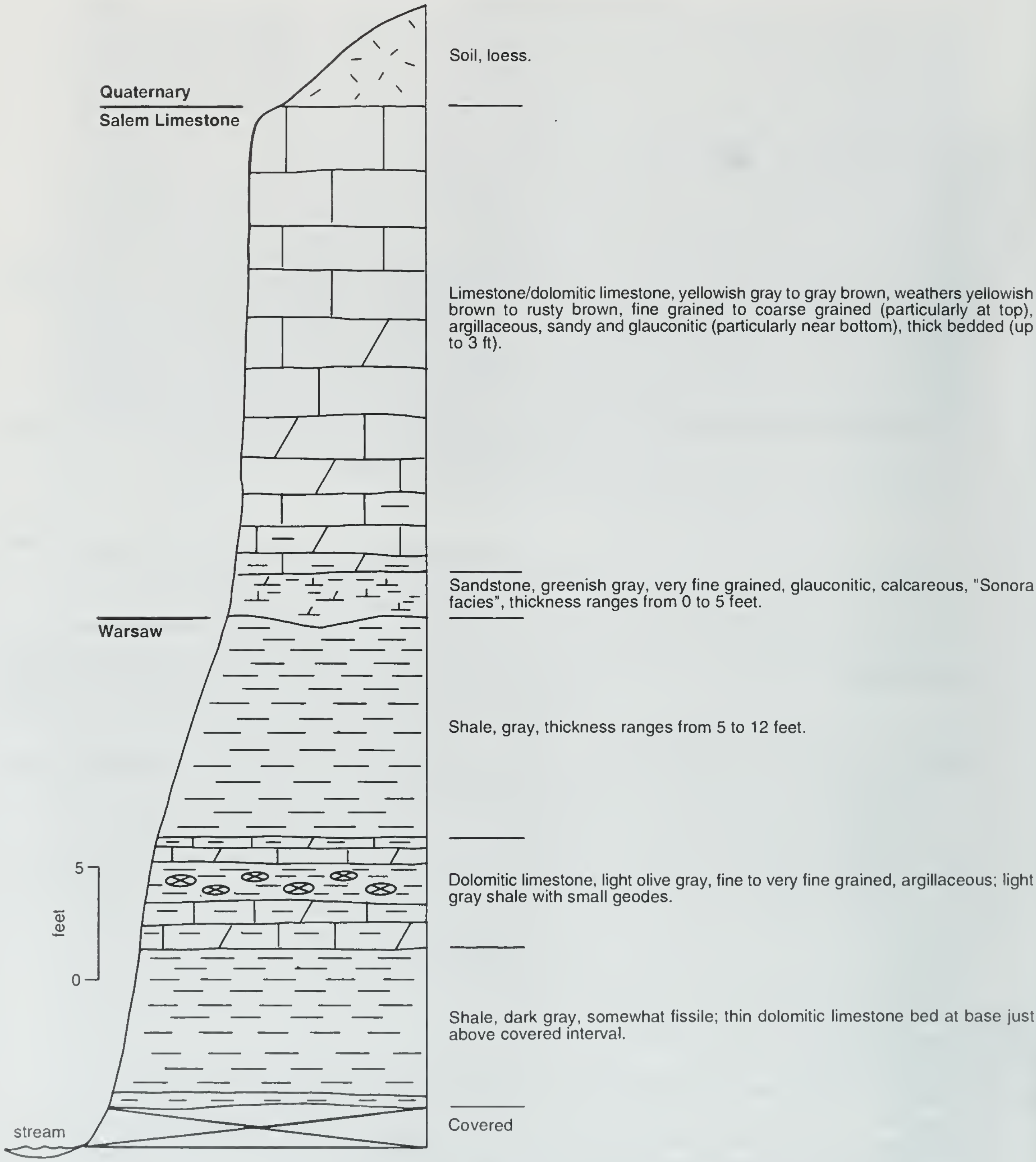


Figure 30 Detailed stratigraphic section of Mississippian rocks exposed along the creek at stop 6, approximately 0.5 mile north of the bridge.

with the aid of a hand lens. Shale, a major component of the Warsaw, is rare in the Salem. Farther downstream (where we probably will not have time to go today), a very fine to fine grained dolomitic and glauconitic sandstone occurs at the base of the Salem (fig. 30). A similar but thinner sandstone also occurs on the floor of the abandoned quarry. This sandstone bed is believed to represent a tongue of the Sonora Sandstone (a lateral, equivalent of the Salem) that is present near the Mississippi River to the northwest. The thickness of the Salem varies within the area; it is at least 20 feet thick further downstream (see fig. 30).

Depositional Environments of the Salem

The Salem was deposited in a clear water, shallow marine environment. The bioclastic limestone of the Salem grades laterally and vertically into microcrystalline (the grains or crystals can only be seen with the aid of a microscope) limestone and dolomite deposited in relatively quiet water environments. Input of silt and clay, common in the Warsaw, was substantially reduced, except for the sandstone bed at the base of the Salem. This decrease in silt and clay was related to reduction in the supply of these materials from emergent land areas, possibly due to a change in climate that reduced the amount of rainfall. The presence of coated carbonate grains in many areas and greater rounding and sorting of fossil fragments indicate the water depth also became shallow enough to allow a high degree of wave and tidal current agitation

St. Louis Limestone

The Salem is overlain by the St. Louis Limestone, which consists of light gray to gray brown, microcrystalline limestone and dolomite that weathers yellow gray to tan. Bioclastic limestone similar to that in the Salem and Warsaw is rare or absent in the St. Louis in this area. Some green shale beds occur in some intervals, indicating a periodic influx of siliciclastic sediments. Some beds are laminated. These laminations, generally known as stromatolites, formed as a result of sediment trapping and binding by blue green algae. The St. Louis also contains evaporite such as gypsum (with water) and anhydrite (without water); both are calcium sulfates. The anhydrite is present only in the subsurface. Brecciated zones (beds where the limestone has been broken in place and recemented) occur within the St. Louis in the outcrops (including this area), and they have been interpreted to result from dissolution of gypsum and anhydrite. A sample from the St. Louis at this stop contains calcite crystals that have the same morphology as gypsum crystals. This similarity indicates that gypsum was formed during deposition of the St. Louis but, because of gypsum's higher solubility, it was later altered to calcite without a change in morphology.

Depositional Environments of the St. Louis

Sedimentary structures such as stromatolites and the presence of evaporite minerals (e.g., gypsum and anhydrite) indicate that the St. Louis was deposited in a much shallower water environment than the Warsaw and Salem. Gradual changes in the environment of deposition from the Warsaw through the St. Louis may be related to changes in climatic conditions. During Warsaw deposition, the climate may have been relatively humid with frequent rainfall, which resulted in abundant input of silt and clay into the sea from highland areas. Siliciclastic input was reduced during Salem deposition, possibly as a result of a drier climatic condition. The climate became more arid and rainfall less frequent during deposition of the St. Louis. This occurrence resulted in an increase in the salinity of the water and led to precipitation of evaporites, such as gypsum and anhydrite. Such an evaporative condition was also conducive to the formation of dolomite by the increasing ratio of magnesium to calcium in the water (due to uptake of calcium during the precipitation of gypsum and anhydrite). Dolomites formed under evaporative conditions are typically microcrystalline, as are the dolomites in the St. Louis in this area.

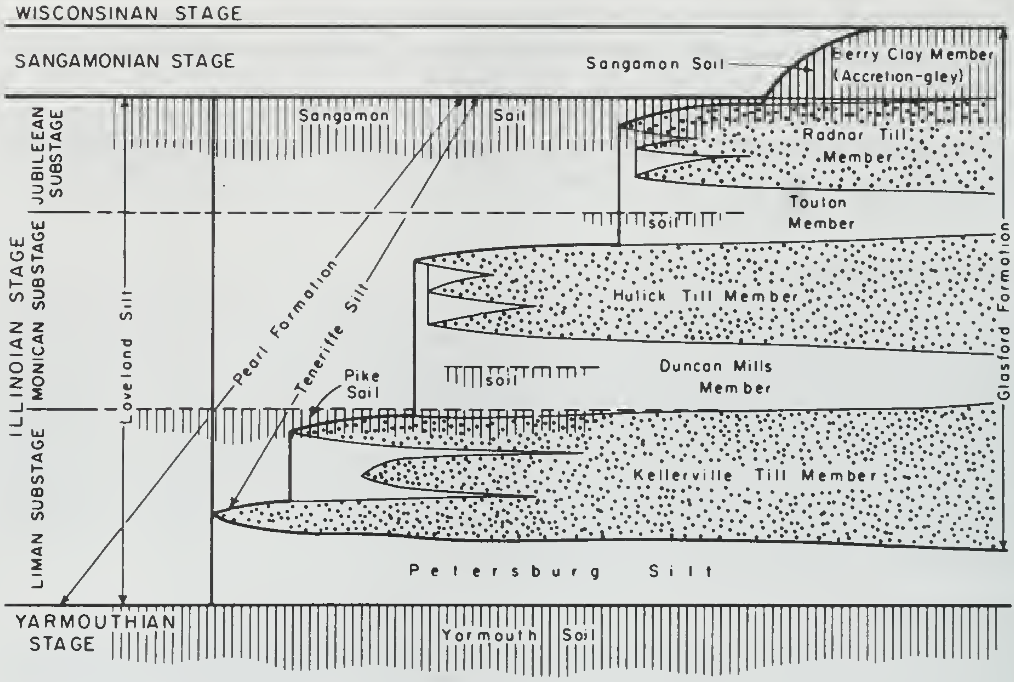


Figure 31 Diagrammatic cross section showing the relationship of formations and members of Illinoian Age in western Illinois (from Lineback 1979).

STOP 7 Langford Cemetery, Exposure of Peoria Loess, Roxana Silt and Sangamon Soil, (Center of Sec. 12, T1S, R2W, 4th P.M., Schuyler County, Cooperstown 7.5-minute Quadrangle [39090H5]).

This roadcut exposes up to 10 feet of loess (Peoria Loess and Roxana Silt) over Sangamon Soil developed in the Hulick Till Member of the Glasford Formation (deposited during the Illinois Episode of glaciation; fig. 31). Toward the east end of the exposure, a particularly striking example of highly oxidized, brownish red, well-drained Sangamon Soil can be seen. This red color is typical of well-drained Sangamon Soil wherever it is exposed on today's landscape. Not all exposures of the Sangamon Soil are, however, this same reddish color. Like the soil on today's landscape, the Sangamon Soil developed on both well-drained and poorly drained areas of the landscape, and only the well-drained areas show this iron-red appearance.

The diamicton in which the soil has developed is highly weathered at this stop, which occurs just east of the "feather-edge" of deposition of the Hulick Till Member of the Glasford Formation. Without considerable sampling and analysis, we do not, in fact, know whether we are actually seeing the Hulick or the Kellerville Till Members of the Glasford (the Kellerville is the basal diamicton of the Glasford west of the Illinois River; the Hulick overlies the Kellerville). If both tills are present and if the Hulick is very thin in this area, the Sangamon Soil, which developed over a span of 50,000 to 100,000 years, has quite likely developed through the entire thickness of the Hulick and well into the Kellerville.

STOP 8 Delbert Ward Quarry (NE, SE, NE, Sec. 3, T1S, R2W, 4th, P.M., Schuyler County, Rushville South 7.5-minute Quadrangle [40090A5]).

The same three Mississippian rock units present at the Cooperstown Stop are also exposed within this abandoned quarry (figs. 32, 33). The Warsaw is present in the quarry floor and presumably several feet below; it extends up to a few feet above the first bench. The Salem occupies most of the lower one-third of the wall of the next bench, and the St. Louis forms the middle third. The upper third includes a thin Pennsylvanian sandstone and conglomerate overlain by Quaternary sediments, including a glacial till, glacial lacustrine sediments, and a moderately thick loess.

The characteristics of the Warsaw at this stop are similar to those of the Warsaw at the Cooperstown Stop, except light gray to olive gray, fine grained, very argillaceous, silty dolomite tends to dominate and the shale and dolomitic shale becomes a minor portion of the formation. Some bioclastic limestone is present near the middle of the unit. This bioclastic limestone contains abundant bryozoans and common echinoderms, brachiopods, and gastropods. The shale and argillaceous dolomites are less fossiliferous. Geodes are present throughout, but they most commonly occur in two distinct zones, one near the top just below a nodular dolomite layer and the other below the bioclastic limestone.

The Salem Limestone, present above the Warsaw, is slightly coarser than the Salem at the Cooperstown Stop. It consists of light gray to light gray brown, clean bioclastic limestones that contain moderately rounded grains of bryozoans, echinoderms, forams, and other fossil fragments. A few thin shale beds or partings are present, especially in the unit overlying the bioclastic interval. The presence of shale suggests occasional input of siliciclastic material from adjacent near shore environments. Additional observations observed at the Cooperstown Stop indicate the Salem was deposited in a shallow marine environment under clear but slightly agitated water conditions.
The St. Louis Limestone overlies the Salem and is very similar to that seen at the Cooperstown Stop. It includes the light gray to brownish gray, microcrystalline limestone and dolomite and three similar green shales near the base of the unit. Some brecciated zones are present. As noted in detail for the Cooperstown Stop, the St. Louis represents a very shallow water environment.

The upper part of the St. Louis and the remainder of the Mississippian rock units are absent in this area, probably due to major erosion that occurred following withdrawal of the sea near the end of the Mississippian or the beginning of the Pennsylvanian Age. The erosional or depositional break such as that between the Mississippian and the overlying Pennsylvanian System is called an unconformity, which in this case, represents several million years. An even larger unconformity between the Pennsylvanian and the more recent Quaternary sediments represents well over 200 million years. The Mississippian-Pennsylvanian unconformity is the result of major streams downcutting into Mississippian sediments and eroding a significant portion of these rocks. Paleovalleys and channels produced by the erosion are now filled with channel deposits of Pennsylvanian sandstone and conglomerate that in part consists of cherts and limestone rock fragments derived from the St. Louis Limestone (fig. 34).

At several places around the quarry, these Pennsylvanian sandstones and conglomerates are present as channel deposits between the St. Louis Limestone and the overlying Quaternary sediments. A thin, black weathered zone (which can be seen but not reached) near the top of the north wall of the quarry is most likely the Pope Creek Coal.

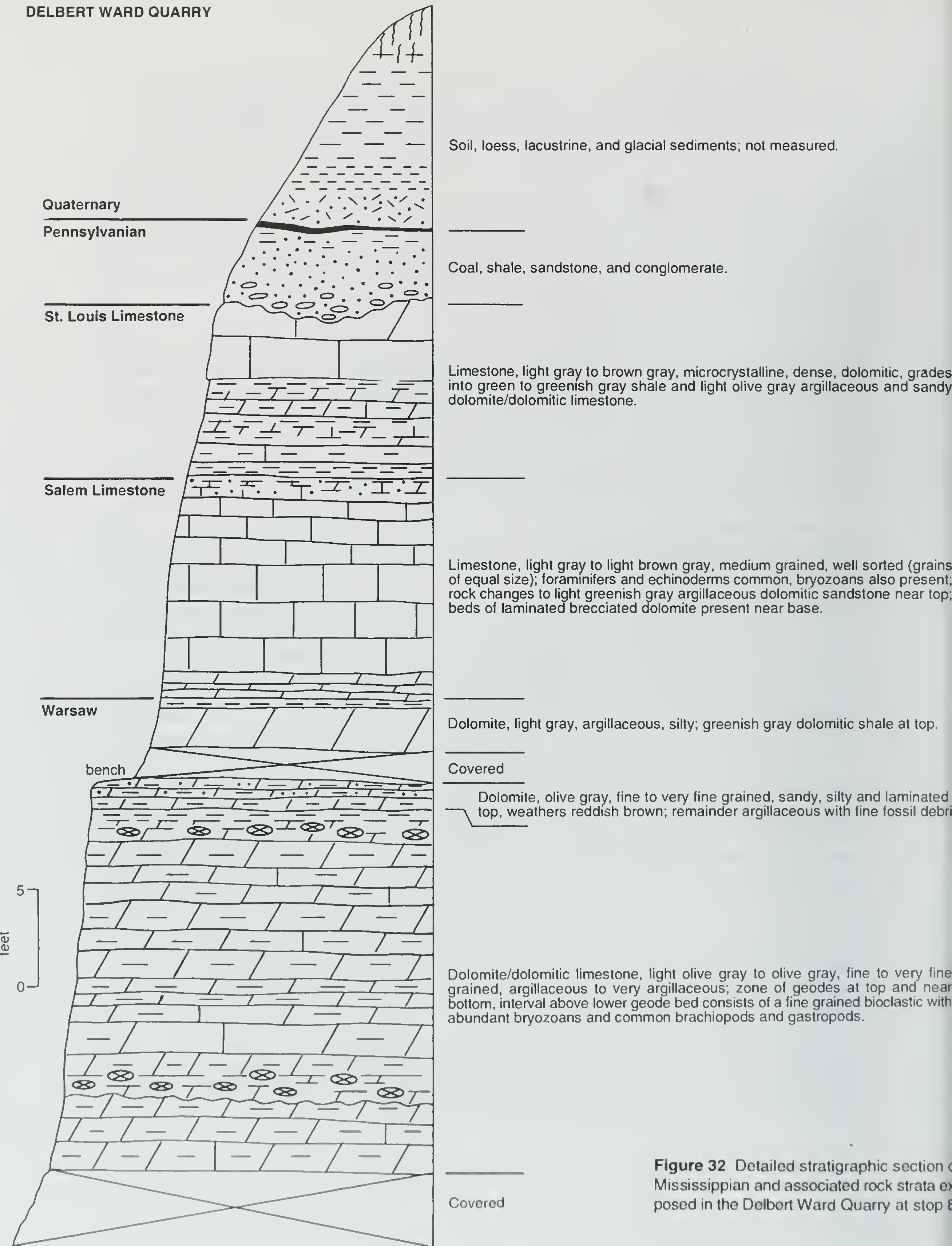


Figure 32 Detailed stratigraphic section c Mississippian and associated rock strata ex posed in the Delbert Ward Quarry at stop 8

Figure 33 Entrance to Delbert Ward Quarry (stop 8). Exposure of limestones and shales of the Warsaw Formation (lower bench), the Salem and St. Louis Limestones (upper bench), and the overlying Pennsylvanian strata and Quaternary sediments (photo by Wayne T. Frankie).

Figure 34 Exposure of lower Pennsylvanian basal conglomerate filling in a small channel in the underlying St. Louis Limestone in the Delbert Ward Quarry (stop 8). The conglomerate contains large weathered chert clasts from the underlying St. Louis and marks an erosional unconformity (photo by Wayne T. Frankie).

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GLOSSARY

The following definitions are from several sources in total or in part, but the main reference is: Bates, R.L., and J.A. Jackson, editors, 1987, Glossary of Geology: American Geological Institute, Alexandria, VA, 3rd Edition, 788 p.

Ablation Separation and removal of rock material and formation of deposits, especially by wind action or the washing away of loose and soluble materials.

Age An interval of geologic time; a division of an epoch.

Aggrading stream One that is actively building up its channel or floodplain by being supplied with more load than it can transport.

Alluviated valley One that has been at least partially filled with sand, silt, and mud by flowing water.

Alluvium A general term for clay, silt, sand, gravel, or similar unconsolidated detrital material deposited during comparatively recent time by a stream or other body of running water as a sorted or semisorted sediment in the bed of a stream or on its floodplain or delta, etc.

Anticline A convex upward rock fold in which strata have been bent into an arch; the strata on each side of the core of the arch are inclined in opposite directions away from the axis or crest; the core contains older rocks than does the perimeter of the structure.

Aquifer A geologic formation that is water-bearing and which transmits water from one point to another

Argillaceous Largely composed of clay-sized particles or clay minerals.

Arenite A relatively clean quartz sandstone that is well sorted and contains less than 10% argillaceous material.

Base level Lowest limit of subaerial erosion by running water, controlled locally and temporarily by water level at stream mouths into lakes or more generally and semipermanently into the ocean (mean sea level).

Basement complex Largely crystalline igneous and/or metamorphic rocks of complex structure and distribution that underlie a sedimentary sequence.

Basin A topographic or structural low area that generally receives thicker deposits of sediments than adjacent areas; the low areas tend to sink more readily, partly because of the weight of the thicker sediments; this also denotes an area of deeper water than found in adjacent shelf areas.

Bed A naturally occurring layer of Earth material of relatively greater horizontal than vertical extent that is characterized by a change in physical properties from those overlying and underlying materials. It also is the ground upon which any body of water rests or has rested, or the land covered by the waters of a stream, lake, or ocean; the bottom of a watercourse or of a stream channel.

Bedrock The solid rock underlying the unconsolidated (non-indurated) surface materials, such as, soil, sand, gravel, glacial till, etc.

Bedrock valley A drainageway eroded into the solid bedrock beneath the surface materials. It may be completely filled with unconsolidated (non-indurated) materials and hidden from view.

Braided stream A low gradient, low volume stream flowing through an intricate network of interlacing shallow channels that repeatedly merge and divide, and are separated from each other by branch islands or channel bars. Such a stream may be incapable of carrying all of its load.

Calcarenite Limestone composed of sand-sized grains consisting of more or less worn shell fragments or pieces of older limestone; a clastic limestone.

Calcareous Containing calcium carbonate ($CaCO_3$); limy.

Calcite A common rock-forming mineral consisting of $CaCO_3$; it may be white, colorless, or pale shades of gray, yellow, and blue; it has perfect rhombohedral cleavage, appears vitreous, and has a hardness of 3 on the Mohs' scale; it effervesces (fizzes) readily in cold dilute hydrochloric acid. It is the principal constituent of limestone.

Chert Silicon dioxide (SiO_2); a compact, massive rock composed of minute particles of quartz and/or chalcedony; it is similar to flint but lighter in color.

Clastic Fragmental rock composed of detritus, including broken organic hard parts as well as rock substances of any sort.

Closure The difference in altitude between the crest of a dome or anticline and the lowest contour that completely surrounds it.

Columnar section A graphic representation in a vertical column of the sequence and stratigraphic relations of the rock units in a region.

Conformable Layers of strata deposited one upon another without interruption in accumulation of sediment; beds parallel.

Delta A low, nearly flat, alluvial land deposited at or near the mouth of a river where it enters a body of standing water; commonly a triangular or fan-shaped plain sometimes extending beyond the general trend of the coastline.

Detritus Material produced by mechanical disintegration.

Disconformity An *unconformity* marked by a distinct erosion-produced irregular, uneven surface of appreciable relief between parallel strata below and above the break; sometimes represents a considerable interval of nondeposition.

Dolomite A mineral, calcium-magnesium carbonate ($Ca,Mg[CO_3]_2$); applied to those sedimentary rocks that are composed largely of the mineral dolomite; it also is precipitated directly from seawater. It is white, colorless, or tinged yellow, brown, pink, or gray; has perfect rhombohedral cleavage; appears pearly to vitreous; effervesces feebly in cold dilute hydrochloric acid.

Drift All rock material transported by a glacier and deposited either directly by the ice or reworked and deposited by meltwater streams and/or the wind.

Driftless Area A 10,000 square mile area in northeastern Iowa, southwestern Wisconsin, and northwestern Illinois where the absence of glacial drift suggests that the area may not have been glaciated.

End moraine A ridge-like or series of ridge-like accumulations of drift built along the margin of an actively flowing glacier at any given time; a moraine that has been deposited at the lower or outer end of a glacier.

Epoch An interval of geologic time; a division of a period.

Era A unit of geologic time that is next in magnitude beneath an eon; consists of two or more periods.

Escarpment A long, more or less continuous cliff or steep slope facing in one general direction, generally marking the outcrop of a resistant layer of rocks.

Fault A fracture surface or zone in Earth materials along which there has been vertical and/or horizontal displacement or movement of the strata on both sides relative to one another.

Floodplain The surface or strip of relatively smooth land adjacent to a stream channel that has been produced by the stream's erosion and deposition actions; the area covered with water when the stream overflows its banks at times of high water; it is built of alluvium carried by the stream during floods and deposited in the sluggish water beyond the influence of the swiftest current.

Fluvial Of or pertaining to a river or rivers.

Formation The basic rock unit distinctive enough to be readily recognizable in the field and widespread and thick enough to be plotted on a map. It describes the strata, such as limestone, sandstone, shale, or combinations of these and other rock types; formations have formal names, such as Joliet Formation or St. Louis Limestone (Formation), usually derived from geographic localities.

Fossil Any remains or traces of an once living plant or animal specimens that are preserved in rocks (arbitrarily excludes Recent remains).

Geology The study of the planet Earth. It is concerned with the origin of the planet, the material and morphology of the Earth, and its history and the processes that acted (and act) upon it to affect its historic and present forms.

Geophysics Study of the Earth by quantitative physical methods.

Glaciation A collective term for the geologic processes of glacial activity, including erosion and deposition, and the resulting effects of such action on the Earth's surface.

Glacier A large, slow-moving mass of ice at least in part on land.

Gradient A part of a surface feature of the Earth that slopes upward or downward; a slope, as of a stream channel or of a land surface.

Igneous Said of a rock or mineral that solidified from molten or partly molten material, i.e., from magma.

Indurated A compact rock or soil hardened by the action of pressure, cementation, and especially heat.

Joint A fracture or crack in rocks along which there has been no movement of the opposing sides.

Karst Area underlain by limestone having many sinkholes separated by steep ridges or irregular hills. Tunnels and caves resulting from solution by groundwater honeycomb the subsurface.

Lacustrine Produced by or belonging to a lake.

Laurasia A combination of Laurentia, a paleogeographic term for the Canadian Shield and its surroundings, and Eurasia. It is the protocontinent of the Northern Hemisphere, corresponding to Gondwana in the Southern Hemisphere, from which the present continents of the Northern Hemisphere have been derived by separation and continental displacement. The hypothetical supercontinent from which both were derived is Pangea. The protocontinent included most of North America, Greenland, and most of Eurasia, excluding India. The main zone of separation was in the North Atlantic, with a branch in Hudson Bay, and geologic features on opposite sides of these zones are very similar.

Limestone A sedimentary rock consisting primarily of calcium carbonate (the mineral, calcite).

Lithify To change to stone, or to petrify; esp. to consolidate from a loose sediment to a solid rock.

Lithology The description of rocks on the basis of color, structures, mineral composition, and grain size; the physical character of a rock.

Local relief The vertical difference in elevation between the highest and lowest points of a land surface within a specified horizontal distance or in a limited area.

Loess A homogeneous, unstratified deposit of silt deposited by the wind.

Magma Naturally occurring mobile rock material or fluid, generated within Earth and capable of intrusion and extrusion, from which igneous rocks are thought to have been derived through solidification and related processes.

Meander One of a series of somewhat regular, sharp, sinuous curves, bends, loops, or turns produced by a stream, particularly in its lower course where it swings from side to side across its valley bottom.

Meander scars Crescent-shaped, concave marks along a river's floodplain that are abandoned meanders, frequently filled in with sediments and vegetation.

Metamorphic rock Any rock derived from pre-existing rocks by mineralogical, chemical, and structural changes, essentially in the solid state, in response to marked changes in temperature, pressure, shearing stress, and chemical environment at depth in Earth's crust (gneiss, schist, marble, quartzite, etc.).

Mineral A naturally formed chemical element or compound having a definite chemical composition and, usually, a characteristic crystal form.

Moraine A mound, ridge, or other distinct accumulation of...glacial drift, predominantly till, deposited in a variety of topographic landforms that are independent of control by the surface on which the drift lies.

Morphology The scientific study of form, and of the structures and development that influence form; term used in most sciences.

Natural gamma log These logs are run in cased, uncased, air, or water-filled boreholes. Natural gamma radiation increases from the left to the right side of the log. In marine sediments, low radiation levels indicate non-argillaceous limestone, dolomite, and sandstone.

Nonconformity An unconformity resulting from deposition of sedimentary strata on massive crystalline rock.

Outwash Stratified drift (clay, silt, sand, gravel) that was deposited by meltwater streams in channels, deltas, outwash plains, on floodplains, and in glacial lakes.

Outwash plain The surface of a broad body of outwash formed in front of a glacier.

Oxbow lake A crescent-shaped lake in an abandoned bend of a river channel.

Pangea A hypothetical supercontinent; supposed by many geologists to have existed at an early time in the geologic past, and to have combined all the continental crust of the Earth, from which the present continents were derived by fragmentation and movement away from each other by means of some form of continental displacement. During an intermediate stage of the fragmentation, between the existence of Pangea and that of the present widely separated continents, Pangea was supposed to have split into two large fragments, *Laurasia* on the north and *Gondwana* on the south. The proto-ocean around Pangea has been termed *Panthalassa*. Other geologists, while believing in the former existence of Laurasia and Gondwana, are reluctant to concede the existence of an original Pangea; in fact, the early (Paleozoic or older) history of continental displacement remains largely undeciphered.

Ped A naturally formed unit of soil structure, e.g. granule, block, crumb, or aggregate.

Peneplain A land surface of regional proportions worn down by erosion to a nearly flat or broadly undulating plain.

Period An interval of geologic time; a division of an era.

Physiography The study and classification of the surface features of Earth on the basis of similarities in geologic strucure and the history of geologic changes.

Physiographic province (or division) (1) A region, all parts of which are similar in geologic structure and climate and which has consequently had a unified geologic history; (2) a region whose pattern of relief features or landforms differs significantly from that of adjacent regions.

Radioactivity logs Logs of bore holes obtained through the use of gamma logging, neutron logging, or combinations of the several radioactivity logging methods.

Relief (a) A term used loosely for the actual physical shape, configuration, or general uneveness of a part of Earth's surface, considered with reference to variations of height and slope or to irregularities of the land surface; the elevations or differences in elevation, considered collectively, of a land surface (frequently confused with topography). (b) The vertical difference in elevation between the hilltops or mountain summits and the lowlands or valleys of a given region; "high relief" has great variation; "low relief" has little variation.

Sediment Solid fragmental material, either inorganic or organic, that originates from weathering of rocks and is transported by, suspended in, or deposited by air, water, or ice, or that is accumulated by other natural agents, such as chemical precipitation from solution or secretion from organisms, and that forms in layers on Earth's surface at ordinary temperatures in a loose, unconsolidated form; e.g, sand, gravel, silt, mud, till, loess, alluvium.

Sedimentary rock A rock resulting from the consolidation of loose sediment that has accumulated in layers (e.g., sandstone, siltstone,limestone).

Sinkholes Small circular depressions that have formed by solution in areas underlain by soluble rocks, most commonly limestone and dolomite.

Stage, substage Geologic time-rock units; the strata formed during an age or subage, respectively.

Stratigraphy the study, definition, and description of major and minor natural divisions of rocks, especially the study of the form, arrangement, geographic distribution, chronologic succession, classification, correlation, and mutual relationships of rock strata.

Stratigraphic unit A stratum or body of strata recognized as a unit in the classification of the rocks of Earth's crust with respect to any specific rock character, property, or attribute or for any purpose such as description, mapping, and correlation.

Stratum A tabular or sheet-like mass, or a single and distinct layer, of homogeneous or gradational sedimentary material of any thickness, visually separable from other layers above and

PLEISTOCENE GLACIATIONS IN ILLINOIS

Origin of the Glaciers

During the past million years or so, an interval of time called the Pleistocene Epoch, most of the northern hemisphere above the 50th parallel has been repeatedly covered by glacial ice. The cooling of the earth's surface, a prerequisite for glaciation, began at least 2 million years ago. On the basis of evidence found in subpolar oceans of the world (temperature-dependent fossils and oxygen-isotope ratios), a recent proposal has been made to recognize the beginning of the Pleistocene at 1.6 million years ago. Ice sheets formed in sub-arctic regions many times and spread outward until they covered the northern parts of Europe and North America. In North America, early studies of the glacial deposits led to the model that four glaciations could explain the observed distribution of glacial deposits. The deposits of a glaciation were separated from each other by the evidence of intervals of time during which soils formed on the land surface. In order of occurrence from the oldest to the youngest, they were given the names Nebraskan, Kansan, Illinoian, and Wisconsinan Stages of the Pleistocene Epoch. Work in the last 30 years has shown that there were more than four glaciations but the actual number and correlations at this time are not known. Estimates that are gaining credibility suggest that there may have been about 14 glaciations in the last one million years. In Illinois, estimates range from 4 to 8 based on buried soils and glacial deposits. For practical purposes, the previous four glacial stage model is functional, but we now know that the older stages are complex and probably contain more than one glaciation. Until we know more, all of the older glacial deposits, including the Nebraskan and Kansan will be classified as pre-Illinoian. The limits and times of the ice movement in Illinois are illustrated in the following pages by several figures.

The North American ice sheets developed when the mean annual temperature was perhaps 4° to 7°C (7° to 13°F) cooler than it is now and winter snows did not completely melt during the summers. Because the time of cooler conditions lasted tens of thousands of years, thick masses of snow and ice accumulated to form glaciers. As the ice thickened, the great weight of the ice and snow caused them to flow outward at their margins, often for hundreds of miles. As the ice sheets expanded, the areas in which snow accumulated probably also increased in extent.

Tongues of ice, called lobes, flowed southward from the Canadian centers near Hudson Bay and converged in the central lowland between the Appalachian and Rocky Mountains. There the glaciers made their farthest advances to the south. The sketch below shows several centers of flow, the general directions of flow from the centers, and the southern extent of glaciation. Because Illinois lies entirely in the central lowland, it has been invaded by glaciers from every center.

Effects of Glaciation

Pleistocene glaciers and the waters melting from them changed the landscapes they covered. The glaciers scraped and smeared the landforms they overrode, leveling and filling many of the minor valleys and even some of the larger ones. Moving ice carried colossal amounts of rock and earth, for much of what the glaciers wore off the ground was kneaded into the moving ice and carried along, often for hundreds of miles.

The continual floods released by melting ice entrenched new drainageways, deepened old ones, and then partly refilled both with sediments as great quantities of rock and earth were carried beyond the glacier fronts. According to some estimates, the amount of water drawn from the sea and changed into ice during a glaciation was enough to lower the sea level from 300 to 400 feet below present level. Consequently, the melting of a continental ice sheet provided a tremendous volume of water that eroded and transported sediments.

In most of Illinois, then, glacial and meltwater deposits buried the old rock-ribbed, low, hill-and-valley terrain and created the flatter landforms of our prairies. The mantle of soil material and the buried deposits of gravel, sand, and clay left by the glaciers over about 90 percent of the state have been of incalculable value to Illinois residents.

Glacial Deposits

The deposits of earth and rock materials moved by a glacier and deposited in the area once covered by the glacier are collectively called **drift**. Drift that is ice-laid is called **till**. Water-laid drift is called **outwash**.

Till is deposited when a glacier melts and the rock material it carries is dropped. Because this sediment is not moved much by water, a till is unsorted, containing particles of different sizes and compositions. It is also stratified (unlayered). A till may contain materials ranging in size from microscopic clay particles to large boulders. Most tills in Illinois are pebbly clays with only a few boulders. For descriptive purposes, a mixture of clay, silt, sand and boulders is called **diamicton**. This is a term used to describe a deposit that could be interpreted as till or a mass wasting product.

Tills may be deposited as **end moraines**, the arc-shaped ridges that pile up along the glacier edges where the flowing ice is melting as fast as it moves forward. Till also may be deposited as **ground moralnes**, or **till plains**, which are gently undulating sheets deposited when the ice front melts back, or retreats. Deposits of till identify areas once covered by glaciers. Northeastern Illinois has many alternating ridges and plains, which are the succession of end moraines and till plains deposited by the Wisconsinan glacier.

Sorted and stratified sediment deposited by water melting from the glacier is called **outwash**. Outwash is bedded, or layered, because the flow of water that deposited it varied in gradient, volume, velocity, and direction. As a meltwater stream washes the rock materials along, it sorts them by size—the fine sands, silts, and clays are carried farther downstream than the coarser gravels and cobbles. Typical Pleistocene outwash in Illinois is in multilayered beds of clays, silts, sands, and gravels that look much like modern stream deposits in some places. In general, outwash tends to be coarser and less weathered, and alluvium is most often finer than medium sand and contains variable amounts of weathered material.

Outwash deposits are found not only in the area covered by the ice field but sometimes far beyond it. Meltwater streams ran off the top of the glacier, in crevices in the ice, and under the ice. In some places, the cobble-gravel-sand filling of the bed of a stream that flowed in the ice is preserved as a sinuous ridge called an **esker**. Some eskers in Illinois are made up of sandy to silty deposits and contain mass wasted diamicton material. Cone-shaped mounds of coarse outwash, called **kames**, were formed where meltwater plunged through crevasses in the ice or into ponds on the glacier.

The finest outwash sediments, the clays and silts, formed bedded deposits in the ponds and lakes that filled glacier-dammed stream valleys, the sags of the till plains, and some low, moraine-diked till plains. Meltwater streams that entered a lake rapidly lost speed and also quickly dropped the sands and gravels they carried, forming deltas at the edge of the lake. Very fine sand and silts were commonly redistributed on the lake bottom by wind-generated currents, and the clays, which stayed in suspension longest, slowly settled out and accumulated with them.

Along the ice front, meltwater ran off in innumerable shifting and short-lived streams that laid down a broad, flat blanket of outwash that formed an **outwash plain**. Outwash was also carried away from the glacier in valleys cut by floods of meltwater. The Mississiippi, Illinois, and Ohio Rivers occupy valleys that were major channels for meltwaters and were greatly widened and deepened during times of the greatest meltwater floods. When the floods waned, these valleys were partly filled with outwash far beyond the ice margins. Such outwash deposits, largely sand and gravel, are known as **valley trains**. Valley train deposits may be both extensive and thick. For instance, the long valley train of the Mississippi Valley is locally as much as 200 feet thick.

Loess, Eolian Sand and Soils

One of the most widespread sediments resulting from glaciation was carried not by ice or water but by wind. **Loess** is the name given to windblown deposits dominated by silt. Most of the silt was derived from wind erosion of the valley trains. Wind action also sorted out **eolian sand** which commonly formed **sand dunes** on the valley trains or on the adjacent uplands. In places, sand dunes have migrated up to 10 miles away from the principle source of sand. Flat areas between dunes are generally underlain by eolian **sheet sand** that is commonly reworked by water action. On uplands along the major valley trains, loess and eolian sand are commonly interbedded. With increasing distance from the valleys, the eolian sand pinches out, often within one mile.

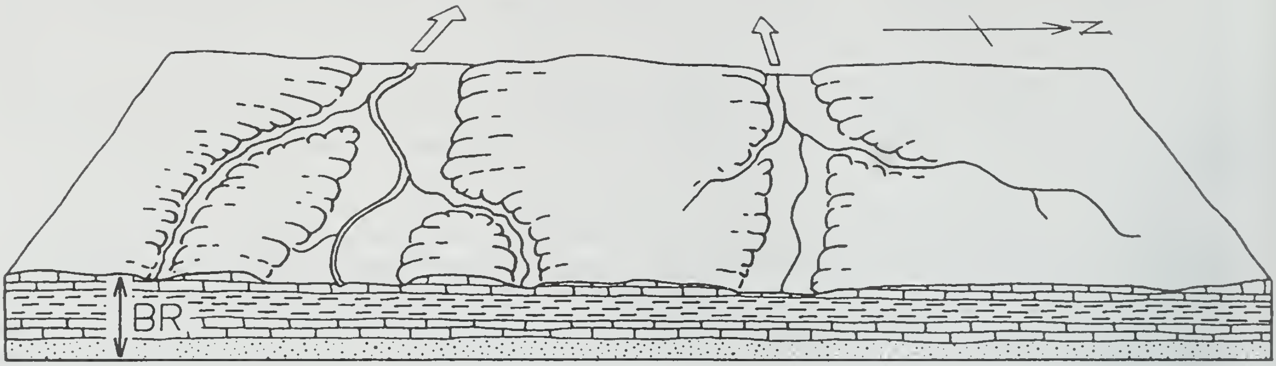
Eolian deposition occurred when certain climatic conditions were met, probably in a seasonal pattern. Deposition could have occurred in the fall, winter or spring season when low precipitation rates and low temperatures caused meltwater floods to abate, exposing the surfaces of the valley trains and permitting them to dry out. During Pleistocene time, as now, west winds prevailed, and the loess deposits are thickest on the east sides of the source valleys. The loess thins rapidly away from the valleys but extends over almost all the state.

Each Pleistocene glaciation was followed by an interglacial stage that began when the climate warmed enough to melt the glaciers and their snowfields. During these warmer intervals, when the climate was similar to that of today, drift and loess surfaces were exposed to weather and the activities of living things. Consequently, over most of the glaciated terrain, soils developed on the Pleistocene deposits and altered their composition, color, and texture. Such soils were generally destroyed by later glacial advances, but some were buried. Those that survive serve as "key beds," or stratigraphic markers, and are evidence of the passage of a long interval of time.

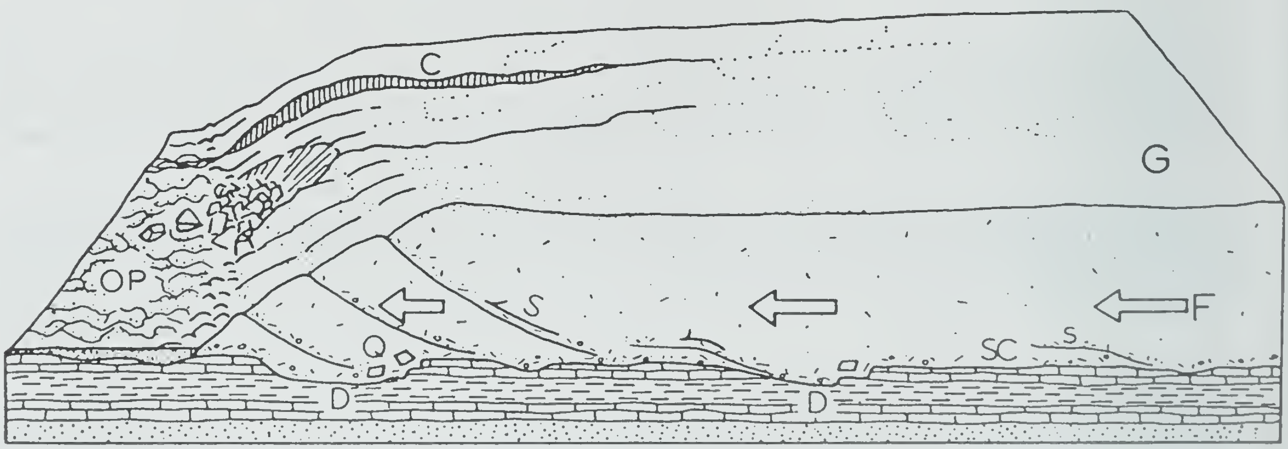
Glaciation in a Small Illinois Region

The following diagrams show how a continental ice sheet might have looked at various stages as it moved across a small region in Illinois. They illustrate how it could change the old terrain and create a landscape like the one we live on. To visualize how these glaciers looked, geologists study the landforms and materials left in the glaciated regions and also the present-day mountain glaciers and polar ice caps.

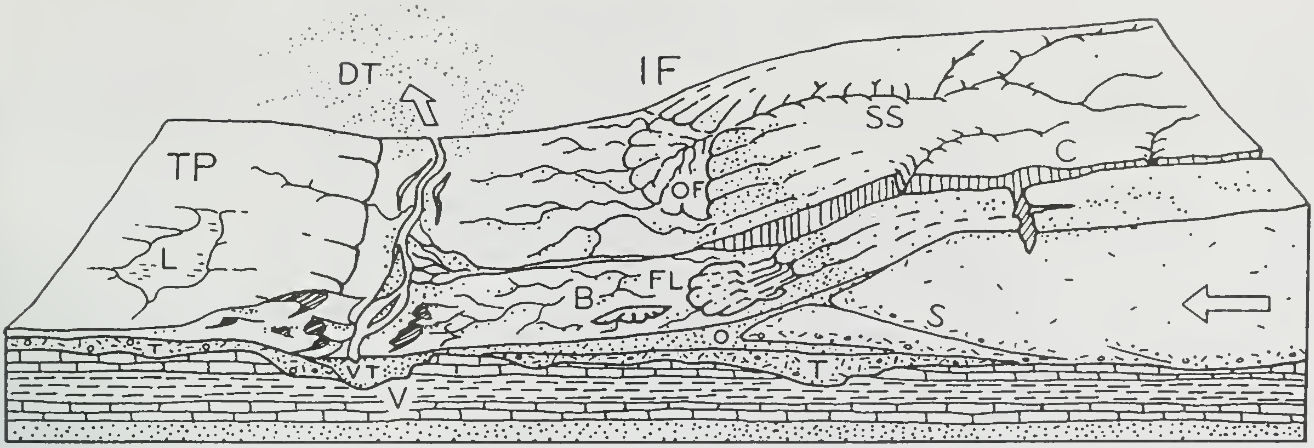
The block of land in the diagrams is several miles wide and about 10 miles long. The vertical scale is exaggerated—layers of material are drawn thicker and landforms higher than they ought to be so that they can be easily seen.



1. **The Region Before Glaciation** — Like most of Illinois, the region illustrated is underlain by almost flat-lying beds of sedimentary rocks—layers of sandstone ( ), limestone ( ), and shale ( ). Millions of years of erosion have planed down the bedrock (BR), creating a terrain of low uplands and shallow valleys. A residual soil weathered from local rock debris covers the area but is too thin to be shown in the drawing. The streams illustrated here flow westward and the one on the right flows into the other at a point beyond the diagram.



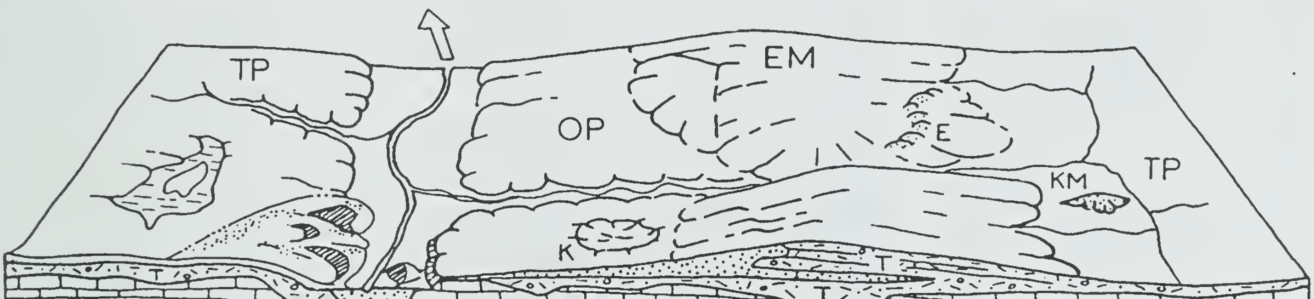
2. **The Glacier Advances Southward** — As the Glacier (G) spreads out from its ice snowfield accumulation center, it scours (SC) the soil and rock surface and quarries (Q)—pushes and plucks up—chunks of bedrock. The materials are mixed into the ice and make up the glacier's "load." Where roughnesses in the terrain slow or stop flow (F), the ice "current" slides up over the blocked ice on innumerable shear planes (S). Shearing mixes the load very thoroughly. As the glacier spreads, long cracks called "crevasses" (C) open parallel to the direction of ice flow. The glacier melts as it flows forward, and its meltwater erodes the terrain in front of the ice, deepening (D) some old valleys before ice covers them. Meltwater washes away some of the load freed by melting and deposits it on the outwash plain (OP). The advancing glacier overrides its outwash and in places scours much of it up again. The glacier may be 5000 or so feet thick, and tapers to the margin, which was probably in the range of several hundred feet above the old terrain. The ice front advances perhaps as much as a third of a mile per year.



3. **The Glacier Deposits an End Moraine** — After the glacier advances across the area, the climate warms and the ice begins to melt as fast as it advances. The ice front (IF) is now stationary, or fluctuating in a narrow area, and the glacier is depositing an end moraine.

As the top of the glacier melts, some of the sediment that is mixed in the ice accumulates on top of the glacier. Some is carried by meltwater onto the sloping ice front (IF) and out onto the plain beyond. Some of the debris slips down the ice front in a mudflow (FL). Meltwater runs through the ice in a crevasse (C). A supraglacial stream (SS) drains the top of the ice, forming an outwash fan (OF). Moving ice has overridden an immobile part of the front on a shear plane (S). All but the top of a block of ice (B) is buried by outwash (O).

Sediment from the melted ice of the previous advance (figure 2) remains as a till layer (T), part of which forms the till plain (TP). A shallow, marshy lake (L) fills a low place in the plain. Although largely filled with drift, the valley (V) remains a low spot in the terrain. As soon as the ice cover melts, meltwater drains down the valley, cutting it deeper. Later, outwash partly refills the valley: the outwash deposit is called a valley train (VT). Wind blows dust (DT) off the dry floodplain. The dust will form a loess deposit when it settles. Sand dunes (D) form on the south and east sides of streams.



4. **The Region after Glaciation** — As the climate warms further, the whole ice sheet melts, and glaciation ends. The end moraine (EM) is a low, broad ridge between the outwash plain (OP) and till plains (TP). Run-off from rains cuts stream valleys into its slopes. A stream goes through the end moraine along the channel cut by the meltwater that ran out of the crevasse in the glacier.

Slopewash and vegetation are filling the shallow lake. The collapse of outwash into the cavity left by the ice block's melting has made a kettle (K). The outwash that filled a tunnel draining under the glacier is preserved in an esker (E). The hill of outwash left where meltwater dumped sand and gravel into a crevasse or other depression in the glacier or at its edge is a kame (KM). A few feet of loess covers the entire area but cannot be shown at this scale.

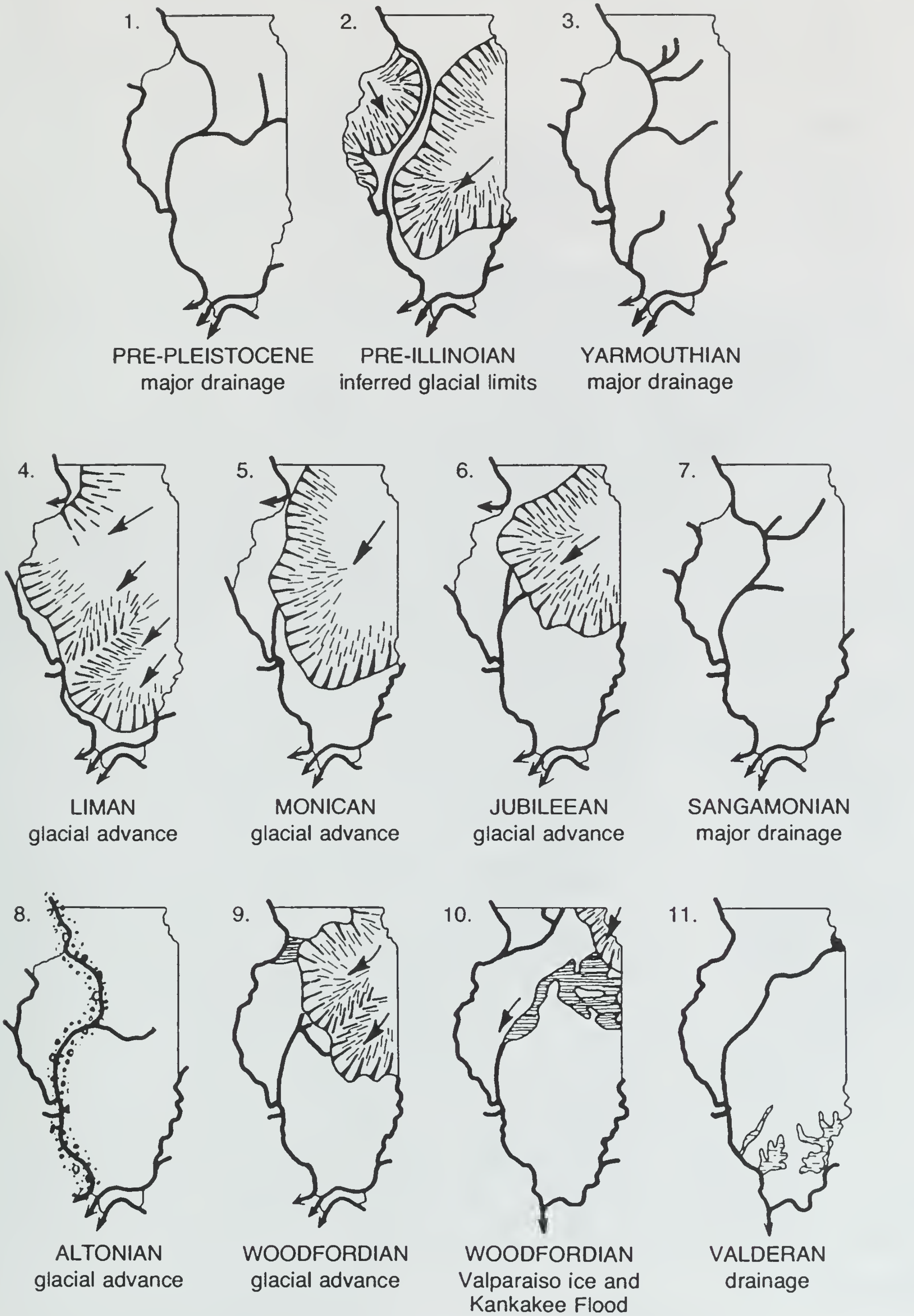
TIME TABLE OF PLEISTOCENE GLACIATION

		STAGE		SUBSTAGE	NATURE OF DEPOSITS	SPECIAL FEATURES
QUATERNARY		HOLOCENE (interglacial)		Years Before Present	Soil, youthful profile of weathering, lake and river deposits, dunes, peat	
				10,000		
	Pleistocene	WISCONSINAN (glacial)	late	Valderan	Outwash, lake deposits	Outwash along Mississippi Valley
				11,000		
				Twocreekan	Peat and alluvium	Ice withdrawal, erosion
				12,500		
				Woodfordian	Drift, loess, dunes, lake deposits	Glaciation; building of many moraines as far south as Shelbyville; extensive valley trains, outwash plains, and lakes
				25,000		
			mid	Farmdalian	Soil, silt, and peat	Ice withdrawal, weathering, and erosion
				28,000		
			early	Altonian	Drift, loess	Glaciation in Great Lakes area, valley trains along major rivers
				75,000		
		SANGAMONIAN (interglacial)			Soil, mature profile of weathering	Important stratigraphic marker
				125,000		
		ILLINOIAN (glacial)		Jubileean	Drift, loess, outwash	Glaciers from northeast at maximum reached Mississippi River and nearly to southern tip of Illinois
				Monican	Drift, loess, outwash	
				Liman	Drift, loess, outwash	
				300,000?		
		YARMOUTHIAN (interglacial)			Soil, mature profile of weathering	Important stratigraphic marker
				500,000?		
	Pre-Illinoian	KANSAN* (glacial)			Drift, loess	Glaciers from northeast and northwest covered much of state
				700,000?		
		AFTONIAN* (interglacial)			Soil, mature profile of weathering	(hypothetical)
				900,000?		
		NEBRASKAN* (glacial)			Drift (little known)	Glaciers from northwest invaded western Illinois
				1,600,000 or more		

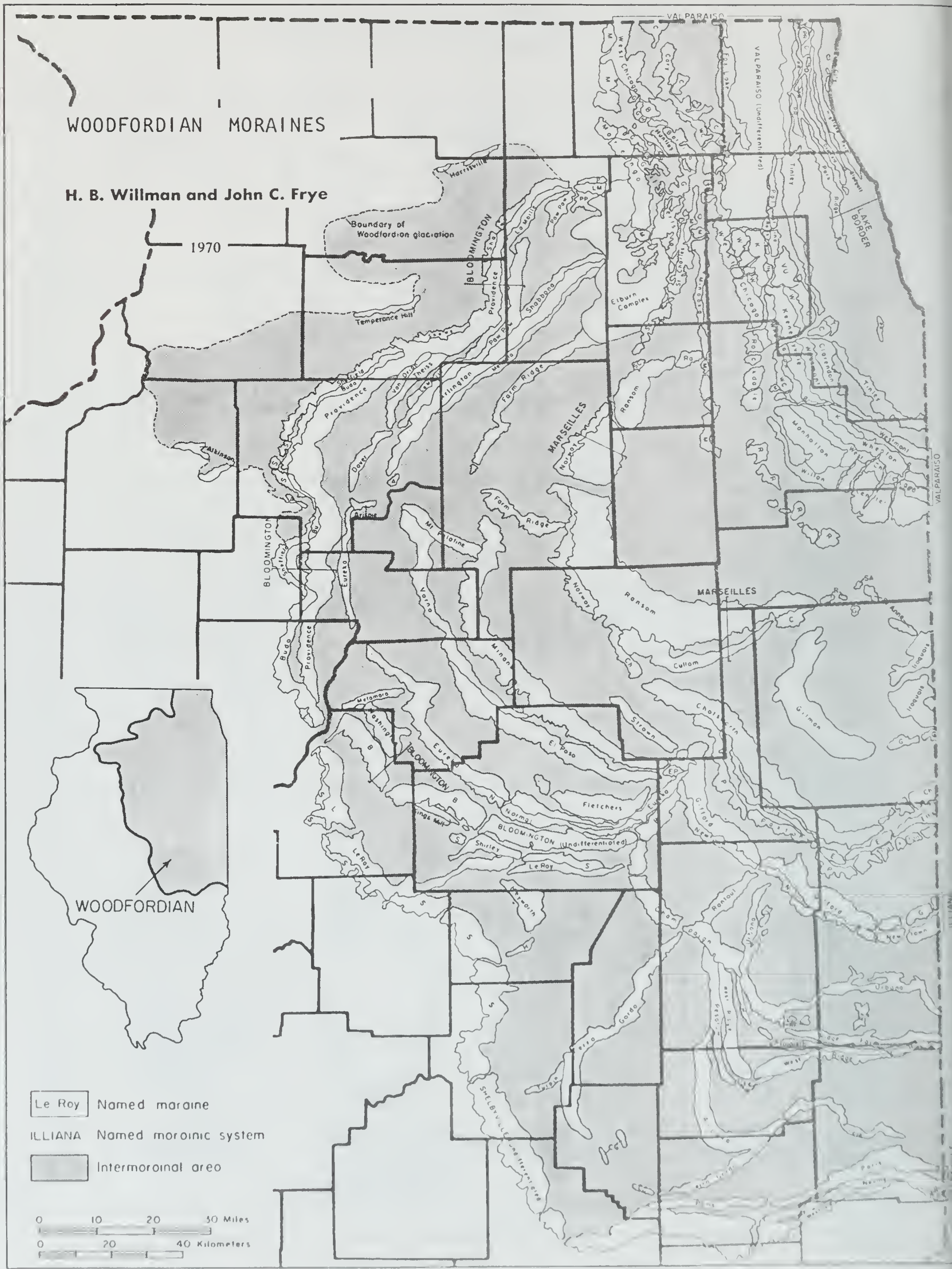
*Old oversimplified concepts, now known to represent a series of glacial cycles.

(Illinois State Geological Survey, 1973

SEQUENCE OF GLACIATIONS AND INTERGLACIAL DRAINAGE IN ILLINOIS



(Modified from Willman and Frye, "Pleistocene Stratigraphy of Illinois," ISGS Bull. 94, fig. 5, 1970.)


WOODFORDIAN MORAINES
H. B. Willman and John C. Frye
1970
Boundary of Woodfordian glaciation
VALPARAISO
VALPARAISO (Undifferentiated)
LAKE BORDER
BLOOMINGTON
MARSEILLES
BLOOMINGTON (Undifferentiated)
SHELBYVILLE (Undifferentiated)
Temperance Hill
Harrisville
Shabbona
Providence
Farm Ridge
Arlington
Mt Palatine
Eureka
Varna
Minonk
Ransom
Cullom
Chatsworth
Strawn
El Paso
Fletchers
Normal
Shirley
Le Roy
Rantoul
Gilman
Iroquois
Elburn Complex
Manhattan
Wheaton
Tinley
Atkinson
Metamora
WOODFORDIAN
Le Roy Named moraine
ILLIANA Named morainic system
Intermorainal area
0 10 20 30 Miles
0 20 40 Kilometers

ILLINOIS STATE GEOLOGICAL SURVEY

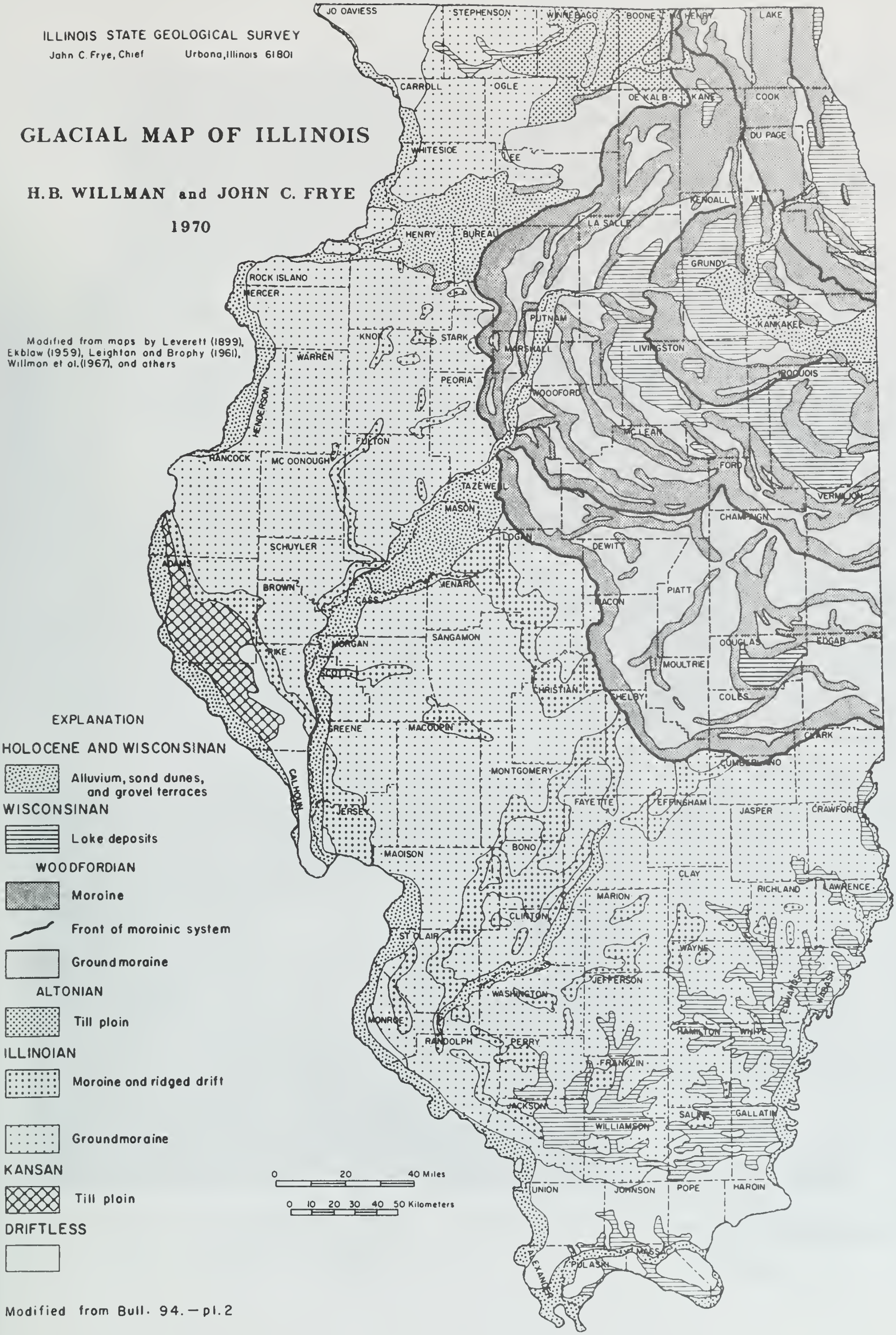
John C. Frye, Chief   Urbana, Illinois 61801

GLACIAL MAP OF ILLINOIS

H. B. WILLMAN and JOHN C. FRYE

1970

Modified from maps by Leverett (1899), Ekblaw (1959), Leighton and Brophy (1961), Willman et al. (1967), and others

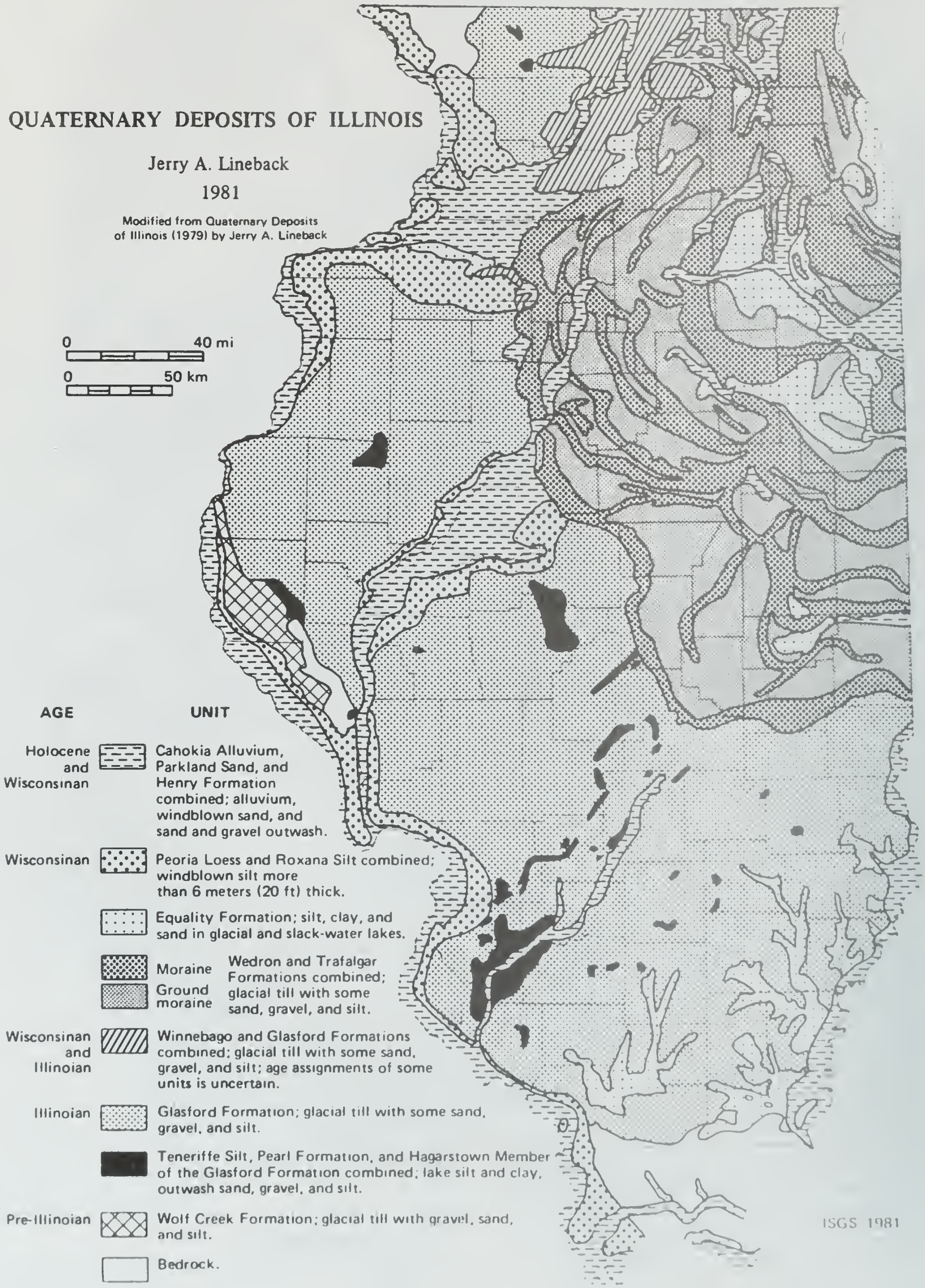


Modified from Bull. 94. — pl. 2

QUATERNARY DEPOSITS OF ILLINOIS

Jerry A. Lineback
1981

Modified from Quaternary Deposits of Illinois (1979) by Jerry A. Lineback



ILLINOIS STATE GEOLOGICAL SURVEY
Urbana. Illinois 61801

GEOGRAM 2
October 1974

ERRATICS ARE ERRATIC

Myrna M. Killey

You may have seen them scattered here and there in Illinois—boulders, some large, some small, lying alone or with a few companions in the corner of a field, at the edge of a road, in someone's yard, or perhaps on a courthouse lawn or schoolyard. Many of them seem out of place, like rough, alien monuments in the stoneless, grassy knolls and prairies of our state. Some—the colorful and glittering granites, banded gneisses, and other intricately veined and streaked igneous and metamorphic rocks—are indeed foreign rocks, for they came from Canada and the states north of us. Others—gray and tan sedimentary rocks—are native rocks and may be no more than a few miles from their place of origin. All of these rocks are glacial boulders that were moved to their present sites by massive ice sheets that flowed across our state. If these boulders are unlike the rocks in the quarries and outcrops in the region where they are found, they are called erratics.

The continental glaciers of the Great Ice Age scoured and scraped the land surface as they advanced, pushing up chunks of bedrock and grinding them against each other or along the ground surface as the rock-laden ice sheets pushed southward. Hundreds of miles of such grinding, even on such hard rocks as granite, eventually rounded off the sharp edges of these passengers in the ice until they became the rounded, irregular boulders we see today. Although we do not know the precise manner in which erratics reached their present isolated sites, many were probably dropped directly from the melting front of a glacier. Others may have been rafted to their present resting places by icebergs on ancient lakes or on the floodwaters of some long-vanished stream as it poured from a glacier. Still others, buried in the glacial deposits, could have worked their way up to the land surface as the surrounding loose soil repeatedly froze and thawed. When the freezing ground expands, pieces of rock tend to be pushed upward, where they are more easily reached by the farmer's plow and also more likely to be exposed by erosion.

An eight-foot boulder of pink granite left by a glacier in the bed of a creek about 5 miles southwest of Alexis, Warren County, Illinois. (From ISGS Bulletin 57, 1929.)

Generally speaking, erratics found northeast of a line drawn from Freeport in Stephenson County, southward through Peoria, and then southeastward through Shelbyville to Marshall at the east edge of the state were brought in by the last glacier to enter Illinois. This glaciation, called the Wisconsinan, spread southwestward into Illinois from a center in eastern Canada, reaching our state about 75,000 years ago and (after repeated advances and retreats of the ice margin) melting from the state about 12,500 years ago. Erratics to the west or south of the great arc outlined above were brought in by a much older glacier, the Illinoian, which spread over most of the state about 300,000 to 175,000 years ago. Some erratics were brought in by even older glaciers that came from the northwest.

You may be able to locate some erratics in your neighborhood. Sometimes it is possible to tell where the rock originally came from by determining the kind of rock it is. A large boulder of granite, gneiss, or other igneous or metamorphic rock may have come from the Canadian Shield, a vast area in central and eastern Canada where rocks of Precambrian age (more than 600 million years old) are exposed at the surface. Some erratics containing flecks of copper were probably transported here from the "Copper Range" of the upper peninsula of Michigan. Large pieces of copper have been found in glacial deposits of central and northern Illinois. Light gray to white quartzite boulders with beautiful, rounded pebbles of red jasper came from a very small outcrop area near Bruce Mines, Ontario, Canada. Purplish pieces of quartzite, some of them banded, probably originated in the Baraboo Range of central Wisconsin. Most interesting of all are the few large boulders of Canadian tillite. Tillite is lithified (hardened into rock) glacial till deposited by a Precambrian glacier many millions of years older than the ones that invaded our state a mere few thousand years ago. Glacial till is an unsorted and unlayered mixture of clay, sand, gravel, and boulders that vary widely in size and shape. Tillite is a gray to greenish gray rock containing a mixture of grains of different sizes and scattered pebbles of various types and sizes.

Many erratics are of notable size and beauty, and in parts of Illinois they are commonly used in landscaping. Some are used as monuments in courthouse squares, in parks, or along highways. Many are marked with metal plaques to indicate an interesting historical spot or event. Keep an eye out for erratics. There may be some of these glacial strangers in your neighborhood that would be interesting to know.

ILLINOIS STATE GEOLOGICAL SURVEY
Urbana, Illinois 61801

GEOGRAM 5
October 1975

ANCIENT DUST STORMS IN ILLINOIS

Myrna M. Killey

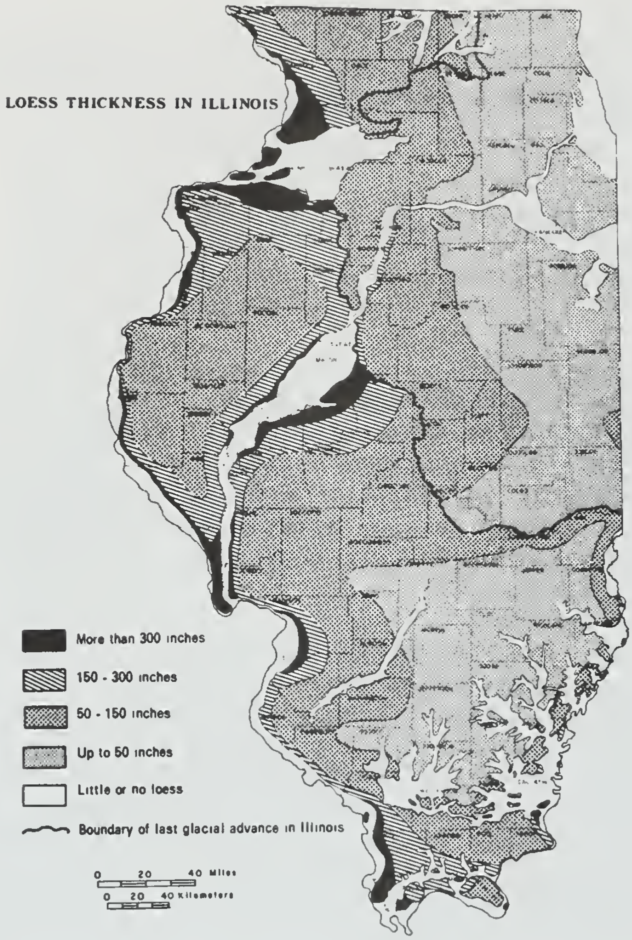
Fierce dust storms whirled across Illinois long before human beings were here to record them. Where did all the dust come from? Geologists have carefully put together clues from the earth itself to get the story. As the glaciers of the Great Ice Age scraped and scoured their way southward across the landscape from Canada, they moved colossal amounts of rock and earth. Much of the rock ground from the surface was kneaded into the ice and carried along, often for hundreds of miles. The glaciers acted as giant grist mills, grinding much of the rock and earth to "flour"—very fine dust-sized particles.

During the warm seasons, water from the melting ice poured from the glacier front, laden with this rock flour, called silt. In the cold months the meltwater stopped flowing and the silt was left along the channels the water had followed, where it dried out and became dust. Strong winds picked up the dust, swept it from the floodplains, and carried it to adjacent uplands. There the forests along the river valleys trapped the dust, which became part of the moist forest soil. With each storm more material accumulated until the high bluffs adjacent to major rivers were formed. The dust deposits are thicker along the eastern sides of the valleys than they are on the western sides, a fact from which geologists deduce that the prevailing winds of that time blew from west to east, the same direction as those of today. From such clues geologists conclude that the geologic processes of the past were much like those of today.

The deposits of windblown silt are called loess (rhymes with "bus"). Loess is found not only in the areas once covered by the glaciers but has been blown into the nonglaciated areas. The glaciers, therefore, influenced the present land surface well beyond the line of their farthest advance.

Loess has several interesting characteristics. Its texture is so fine and uniform that it can easily be identified in roadcuts—and because it blankets such a vast area many roads are cut through it. Even more noticeable is its tendency to stand in vertical walls. These steep walls develop as the loess drains and becomes tough, compact, and massive, much like a rock. Sometimes cracks develop in the loess, just as they do in massive limestones and sandstones. Loess makes good highway banks if it is cut vertically. A vertical cut permits maximum drainage because little surface is exposed to rain, and rainwater tends to drain straight down through it to the rock underneath. If the bank is cut at an angle more water soaks in, which causes the loess to slump down. Along Illinois roads the difference between a loess roadcut and one in ordinary glacial till is obvious. The loess has a very uniform texture, while the till is composed of a random mixture of rock debris, from clay and silt through cobbles and boulders.

Many loess deposits are worth a close look. Through a 10-power hand lens separate grains can be seen, among them many clear, glassy, quartz grains. Some loess deposits contain numerous rounded, lumpy stones called concretions. Their formation began when water percolating through the loess dissolved tiny



limestone grains. Some of the dissolved minerals later became solid again, gathering around a tiny nucleus or along roots to form the lumpy masses. A few such concretions are shaped roughly like small dolls and, from this resemblance, are called "loess kindchen," a German term meaning "loess children." They may be partly hollow and contain smaller lumps that make them rattle when shaken.

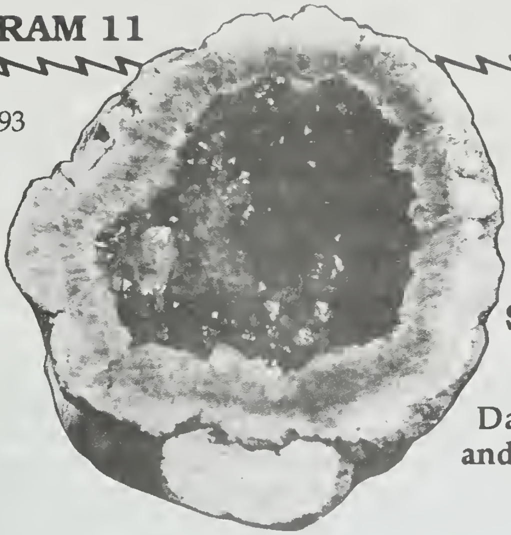
Fossil snails can be found in some loess deposits. The snails lived on the river bluffs while the loess was being deposited and were buried by the dust. When they are abundant, they are used to determine how old the loess is. The age is found by measuring the amount of radioactive carbon in the calcium carbonate of their shells.

Some of the early loess deposits were covered by new layers of loess following later glacial invasions. Many thousands of years passed between the major glacial periods, during which time the climate was as warm as that of today. During the warm intervals, the surface of the loess and other glacial deposits was exposed to weather. Soils developed on most of the terrain, altering the composition, color, and texture of the glacial material. During later advances of the ice, some of these soils were destroyed, but in many places they are preserved under the younger sediments. Such ancient buried soils can be used to determine when the materials above and below them were laid down by the ice and what changes in climate took place.

The blanket of loess deposited by the ancient dust storms forms the parent material of the rich, deep soils that today are basic to the state's agriculture. A soil made of loess crumbles easily and has great moisture-holding capacity. It also is free from rocks that might complicate cultivation. Those great dust storms that swirled over the land many thousands of years ago thus endowed Illinois with one of its greatest resources, its highly productive soil.

GEOGRAM 11 ILLINOIS STATE GEOLOGICAL SURVEY

March 1993



GEODES

Small Treasure Vaults in Illinois

David L. Reinertsen, D. Scott Beaty,
and Jonathan H. Goodwin

Geodes, a term derived from a Greek word meaning earth-shaped, are irregular, roughly spherical bodies. They can be oblong or shaped like invertebrate fossils (e.g. crinoid calyx). Some are hollow and lined with beautiful layers and clusters of various mineral crystals, but others are completely filled by inward-growing crystals. Hollow geodes, relatively lightweight compared with those completely filled, are more desirable because they generally contain a greater variety of minerals that have had an opportunity to grow well formed crystals. Some of Illinois' best mineral specimens were collected from the crystal linings of geodes.

Geodes found in Illinois range from less than 1 inch to more than 2 feet in diameter, but 3 to 5 inches is the average. They generally occur in limestone, a calcium carbonate ($CaCO_3$), or in dolomite, a calcium-magnesium carbonate ($CaMg(CO_3)_2$). Although geodes can be found in carbonate-rich rocks throughout the state, one of the most famous geode collecting areas in the country is the region of western Illinois and adjacent parts of Iowa and Missouri. The region encompasses about a 70-mile radius from the towns of Warsaw, Hamilton, and Nauvoo.

A typical geode from western Illinois has an outer shell made of chalcedony, a cryptocrystalline quartz composed of silicon dioxide (SiO_2). Once the outer shell forms, mineral-rich water may still be inside the shell, causing more quartz to be deposited and other minerals to form toward the center. Chalcedony, much harder than the host rock of limestone, helps to preserve the specimen during weathering. As the weaker host rock is eroded, the geodes "weather out" and remain behind. They generally are easy to see because of their shape and the texture of their outer shell.

The micro-environment inside the shell is an excellent place for crystal growth. Temperature and pressure changes, as well as evaporation, cause the mineral matter to precipitate. More solutions rich in minerals may seep into the geode later, adding to the quartz crystals or forming other minerals. In addition to the chalcedony of the outer shell, the inside of some geodes is lined with a pronounced bumpy, mammillary form of blue-gray chalcedony. Some specimens also have excellent clear quartz crystals. Ankerite, aragonite, calcite, dolomite, goethite/limonite, gypsum, and marcasite/pyrite are the other minerals most commonly found. Occasionally, dark bronze, fine, hair-like masses are found inside; these may be millerite (NiS) or a filamentous form of pyrite.

Perhaps the most fascinating geodes are those that contain petroleum, which may be under enough pressure to squirt out when the geode is broken. The enclosing rock north of Nauvoo, where these unusual geodes are found, no longer contains any significant oil. So what is the source of oil in these geodes? What is the origin of the other minerals? We don't know for sure. Perhaps trace amounts of some of the elements that make up the rarer minerals were present in shale layers associated with the carbonate strata. As a matter of fact, the most prolific zone for collecting geodes in western Illinois is in the lower part of the Warsaw Shale of the Valmeyeran Series (middle series of the Mississippian System). These sedimentary strata were deposited in shallow seas that covered what is now the midcontinent about 350 million years ago.

Geologists have proposed several theories to explain the conditions and processes that form geodes, but none seems to be entirely adequate to explain all geode features. In discussing the origin of the western Illinois geodes, Hayes (1964) noted that any theory proffered must explain why the geodes are

(1) essentially confined to a specific stratigraphic interval, the lower part of the Warsaw Shale;

(2) generally associated with particular lithologies (clayey, shaley dolomite, and dolomitic mudstone);

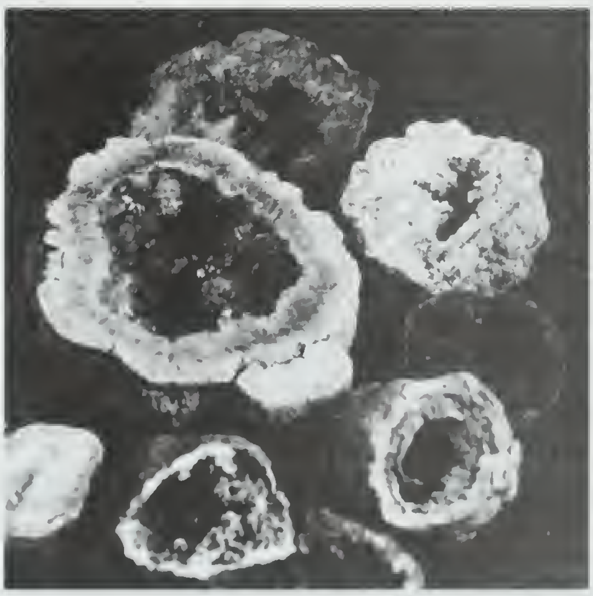
(3) located in specific zones or beds rather than scattered randomly;

(4) fairly uniform in size in a particular zone and round, at least initially;

(5) enveloped by laminations in the bedrock that exhibit some thinning of layers above and below the specimen.

As limey sediments accumulated in shallow midcontinental seas, rounded cavities that are characteristic of geodes could not have formed at the interface or contact of water and sediments. Nor could they have formed during the earliest stages of sediment compaction and cementation. Therefore, some feature of a different texture than the host limestone had to be present. This feature either caused geodes to form or was transformed into a geode. Hayes hypothesized that the only features in the rocks that shared enough characteristics with geodes to serve as precursors were calcite concretions (small zones in the original sediment strongly cemented by calcite). The size and shape of these concretions, their position in the limestone, and their relation to the surrounding rocks are strikingly similar to those of geodes. In several exposures in the region, specimens may be found that display all stages of the transition from concretion to geode. Hayes suggested that calcite concretions formed where organic materials (remains of the living tissues of plants or animals) accumulated with carbonate-rich sediments under quiet-water conditions. The organic matter decomposed, causing an oxygen-poor (anaerobic), alkaline environment (pH >7) to develop in the sediments. These conditions encouraged calcite to precipitate from the solutions in the sediments.

The formation of many features seen in geodes may involve a step by step replacement of these concretions by quartz and other minerals. Changes in the chemical composition and acidity (pH) of water in the sediments caused chalcedony to replace the calcite at the outer margins of the concretions. This process caused the formation of a calcite-concretion core surrounded by a hard, but slightly permeable, shell of chalcedony. Further changes in the chemistry and pH of the water percolating slowly through the sediment caused the core concretion inside the geode eventually to dissolve, leaving a hard, hollow cavity in which more chalcedony, quartz, or other minerals could precipitate.



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Illinois State Geological Survey
615 East Peabody Drive
Champaign, IL 61820-6964

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DEPOSITIONAL HISTORY OF THE PENNSYLVANIAN ROCKS IN ILLINOIS

At the close of the Mississippian Period, about 310 million years ago, the sea withdrew from the Midcontinent region. A long interval of erosion that took place early in Pennsylvanian time removed hundreds of feet of the pre-Pennsylvanian strata, completely stripping them away and cutting into older rocks over large areas of the Midwest. Ancient river systems cut deep channels into the bedrock surface. Later, but still during early Pennsylvanian (Morrowan) time, the sea level started to rise; the corresponding rise in the base level of deposition interrupted the erosion and led to filling the valleys in the erosion surface with fluvial, brackish, and marine sands and muds.

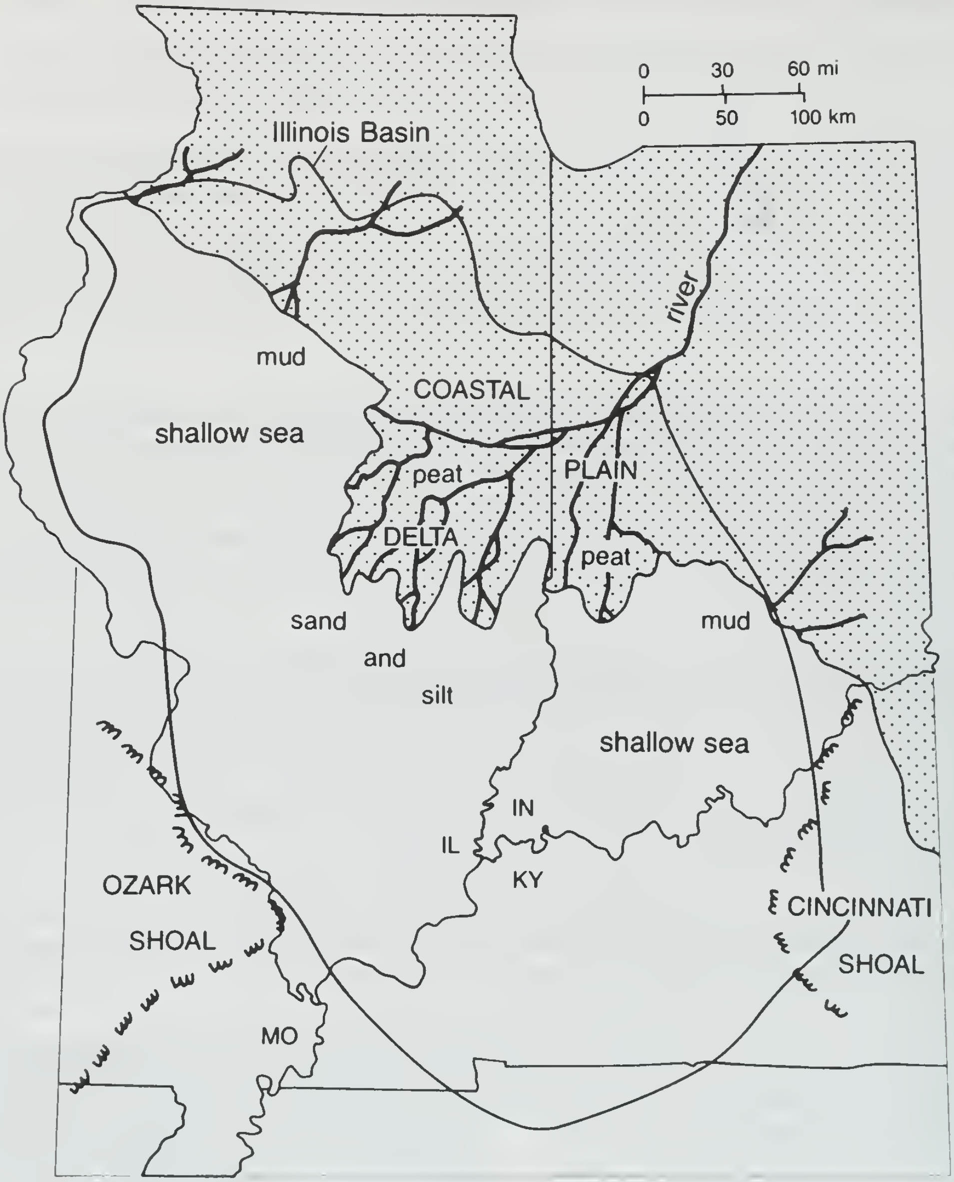
Depositional conditions in the Illinois Basin during the Pennsylvanian Period were somewhat similar to those of the preceding Chesterian (late Mississippian) time. A river system flowed southwestward across a swampy lowland, carrying mud and sand from highlands to the northeast. This river system formed thin but widespread deltas that coalesced into a vast coastal plain or lowland that prograded (built out) into the shallow sea that covered much of present-day Illinois (see paleogeographic map, next page). As the lowland stood only a few feet above sea level, slight changes in relative sea level caused great shifts in the position of the shoreline.

During most of Pennsylvanian time, the Illinois Basin gradually subsided; a maximum of about 3000 feet of Pennsylvanian sediments are preserved in the basin. The locations of the delta systems and the shoreline of the resulting coastal plain shifted, probably because of worldwide sea level changes, coupled with variation in the amounts of sediments provided by the river system and local changes in basin subsidence rates. These frequent shifts in the coastline position caused the depositional conditions at any one locality in the basin to alternate frequently between marine and nonmarine, producing a variety of lithologies in the Pennsylvanian rocks (see lithology distribution chart).

Conditions at various places on the shallow sea floor favored the deposition of sand, lime mud, or mud. Sand was deposited near the mouths of distributary channels, where it was reworked by waves and spread out as thin sheets near the shore. Mud was deposited in quiet-water areas — in delta bays between distributaries, in lagoons behind barrier bars, and in deeper water beyond the nearshore zone of sand deposition. Limestone was formed from the accumulation of limy parts of plants and animals laid down in areas where only minor amounts of sand and mud were being deposited. The areas of sand, mud, and limy mud deposition continually changed as the position of the shoreline changed and as the delta distributaries extended seaward or shifted their positions laterally along the shore.

Nonmarine sand, mud, and lime mud were deposited on the coastal plain bordering the sea. The nonmarine sand was deposited in delta distributary channels, in river channels, and on the broad floodplains of the rivers. Some sand bodies 100 or more feet thick were deposited in channels that cut through the underlying rock units. Mud was deposited mainly on floodplains. Some mud and freshwater lime mud were deposited locally in fresh-water lakes and swamps.

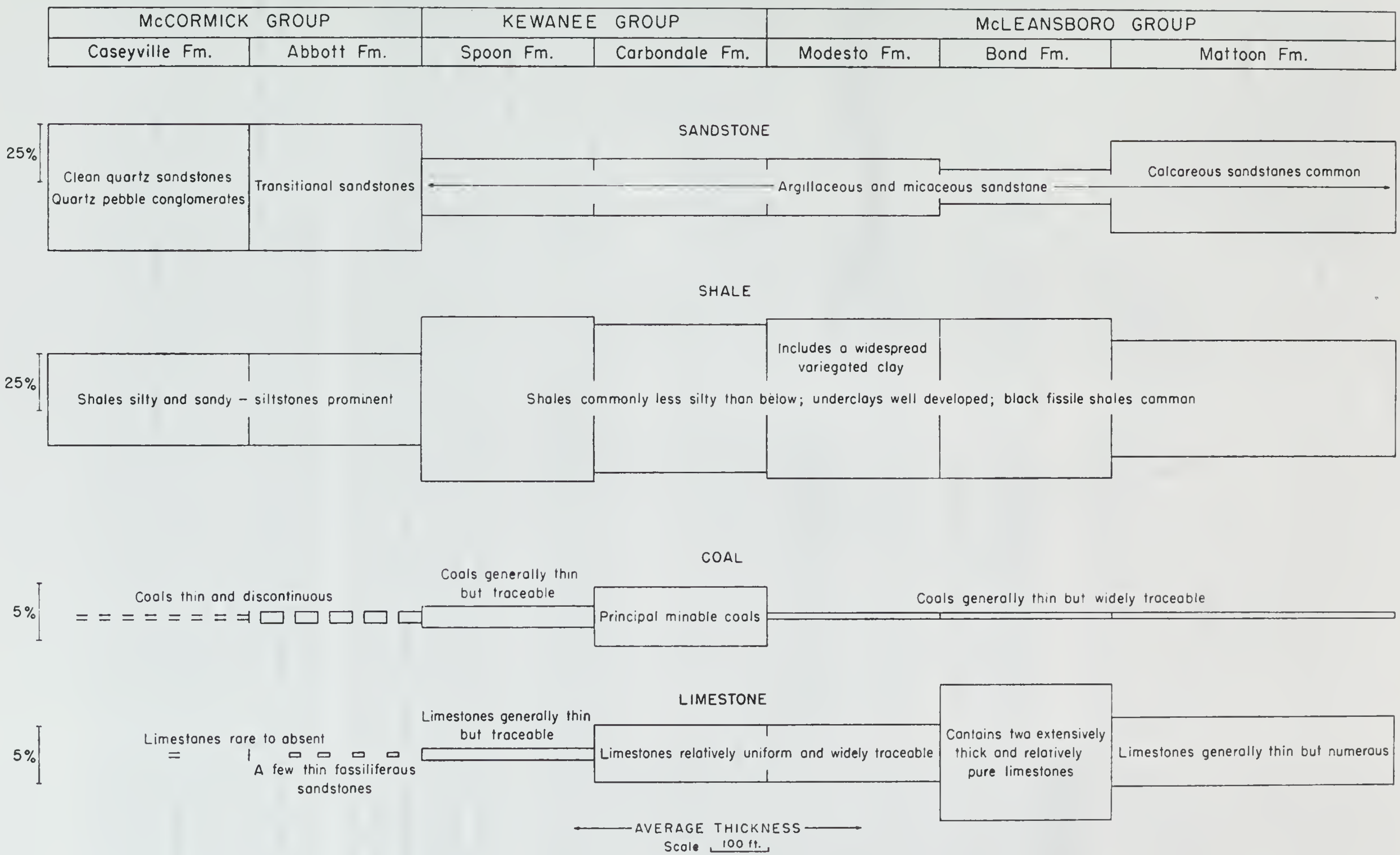
Beneath the quiet water of extensive swamps that prevailed for long intervals on the emergent coastal lowland, peat was formed by accumulation of plant material. Lush forest vegetation covered the region; it thrived in the warm, moist Pennsylvanian-age climate. Although the origin of the underclays beneath the coal is not precisely known, most evidence indicates that they were deposited in the swamps as slackwater mud before the accumulation of much plant debris. The clay underwent modification to become the soil upon which the lush vegetation grew in the swamps. Underclay frequently contains plant roots and rootlets that appear to be in their original places. The vast swamps were the culmination of nonmarine deposition. Resubmergence of the borderlands by the sea interrupted nonmarine deposition, and marine sediments were laid down over the peat.



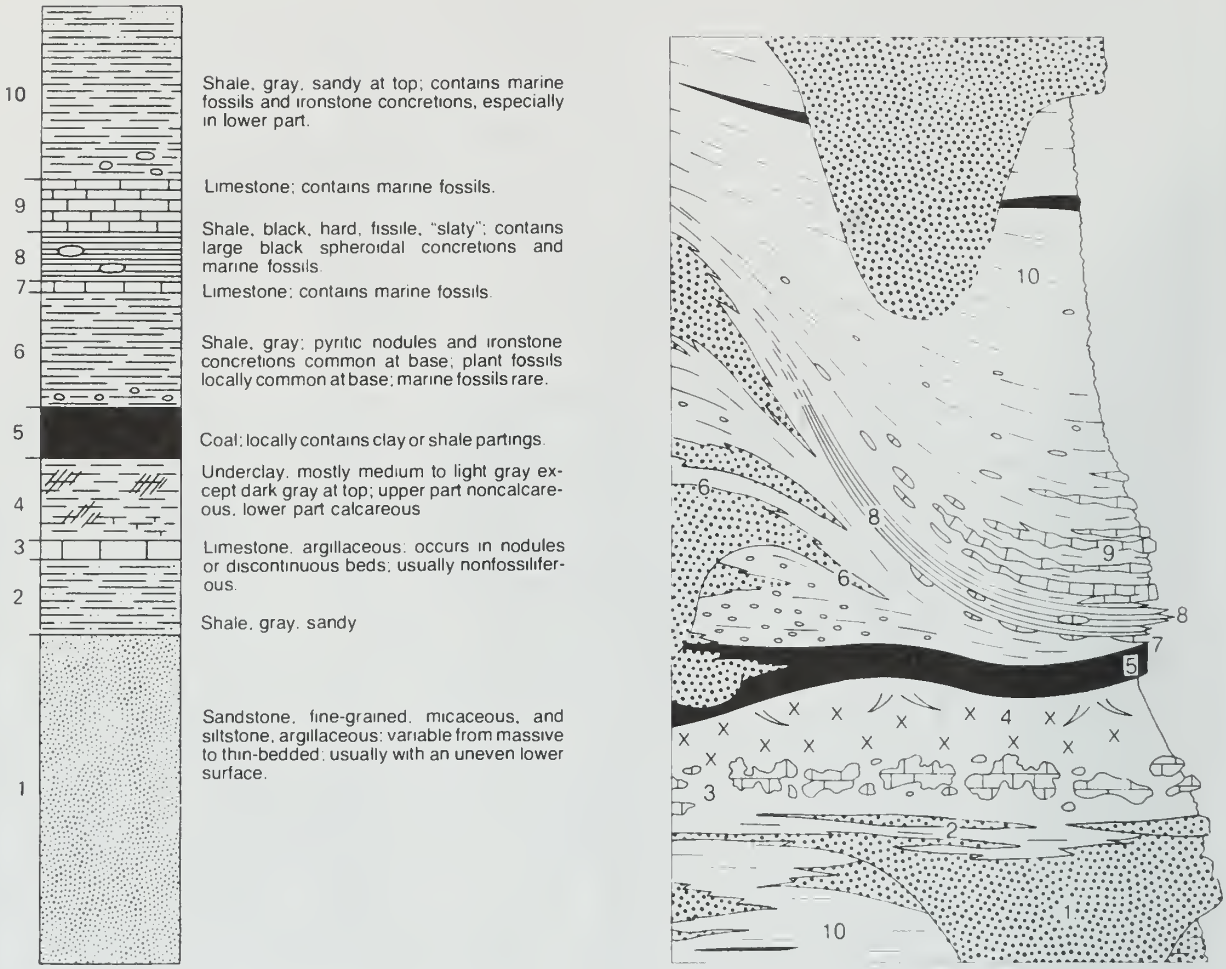
Paleogeography of Illinois-Indiana region during Pennsylvanian time. The diagram shows a Pennsylvanian river delta and the position of the shoreline and the sea at an instant of time during the Pennsylvanian Period.

Pennsylvanian Cyclothems

The Pennsylvanian strata exhibit extraordinary variations in thickness and composition both laterally and vertically because of the extremely varied environmental conditions under which they formed. Individual sedimentary units are often only a few inches thick and rarely exceed 30 feet thick. Sandstones and shales commonly grade laterally into each other, and shales sometimes interfinger and grade into limestones and coals. The underclays, coals, black shales, and some limestones, however, display remarkable lateral continuity for such thin units. Coal seams have been traced in mines, outcrops, and subsurface drill records over areas comprising several states.



General distribution of the four principal lithologies in Pennsylvanian strata of Illinois.



The idealized cyclothem at left (after Willman and Payne, 1942) infers continuous, widespread distribution of individual cyclothem units, at right the model of a typical cyclothem (after Baird and Shabica, 1980) shows the discontinuous nature of many units in a cyclothem.

The rapid and frequent changes in depositional environments during Pennsylvanian time produced regular or cyclical alternations of sandstone, shale, limestone, and coal in response to the shifting shoreline. Each series of alternations, called a cyclothem, consists of several marine and nonmarine rock units that record a complete cycle of marine invasion and retreat. Geologists have determined, after extensive studies of the Pennsylvanian strata in the Midwest, that an "ideally" complete cyclothem consists of ten sedimentary units (see illustration above contrasting the model of an "ideal" cyclothem with a model showing the dynamic relationships between the various members of a typical cyclothem).

Approximately 50 cyclothems have been described in the Illinois Basin but only a few contain all ten units at any given location. Usually one or more are missing because conditions of deposition were more varied than indicated by the "ideal" cyclothem. However, the order of units in each cyclothem is almost always the same: a typical cyclothem includes a basal sandstone overlain by an underclay, coal, black sheety shale, marine limestone, and gray marine shale. In general, the sandstone-underclay-coal-gray shale portion (the lower six units) of each cyclothem is nonmarine: it was deposited as part of the coastal lowlands from which the sea had withdrawn. However, some of the sandstones are entirely or partly marine. The units above the coal and gray shale are marine sediments deposited when the sea advanced over the coastal plain.

Origin of Coal

It is generally accepted that the Pennsylvanian coals originated by the accumulation of vegetable matter, usually in place, beneath the waters of extensive, shallow, fresh-to-brackish swamps. They represent the last-formed deposits of the nonmarine portions of the cyclothems. The swamps occupied vast areas of the coastal lowland, which bordered the shallow Pennsylvanian sea. A luxuriant growth of forest plants, many quite different from the plants of today, flourished in the warm, humid Pennsylvanian climate. (Illinois at that time was near the equator.) The deciduous trees and flowering plants that are common today had not yet evolved. Instead, the jungle-like forests were dominated by giant ancestors of present-day club mosses, horsetails, ferns, conifers, and cycads. The undergrowth also was well developed, consisting of many ferns, fernlike plants, and small club mosses. Most of the plant fossils found in the coals and associated sedimentary rocks show no annual growth rings, suggesting rapid growth rates and lack of seasonal variations in the climate (tropical). Many of the Pennsylvanian plants, such as the seed ferns, eventually became extinct.

Plant debris from the rapidly growing swamp forests — leaves, twigs, branches, and logs — accumulated as thick mats of peat on the floors of the swamps. Normally, vegetable matter rapidly decays by oxidation, forming water, nitrogen, and carbon dioxide. However, the cover of swamp water, which was probably stagnant and low in oxygen, prevented oxidation, and any decay of the peat deposits was due primarily to bacterial action.

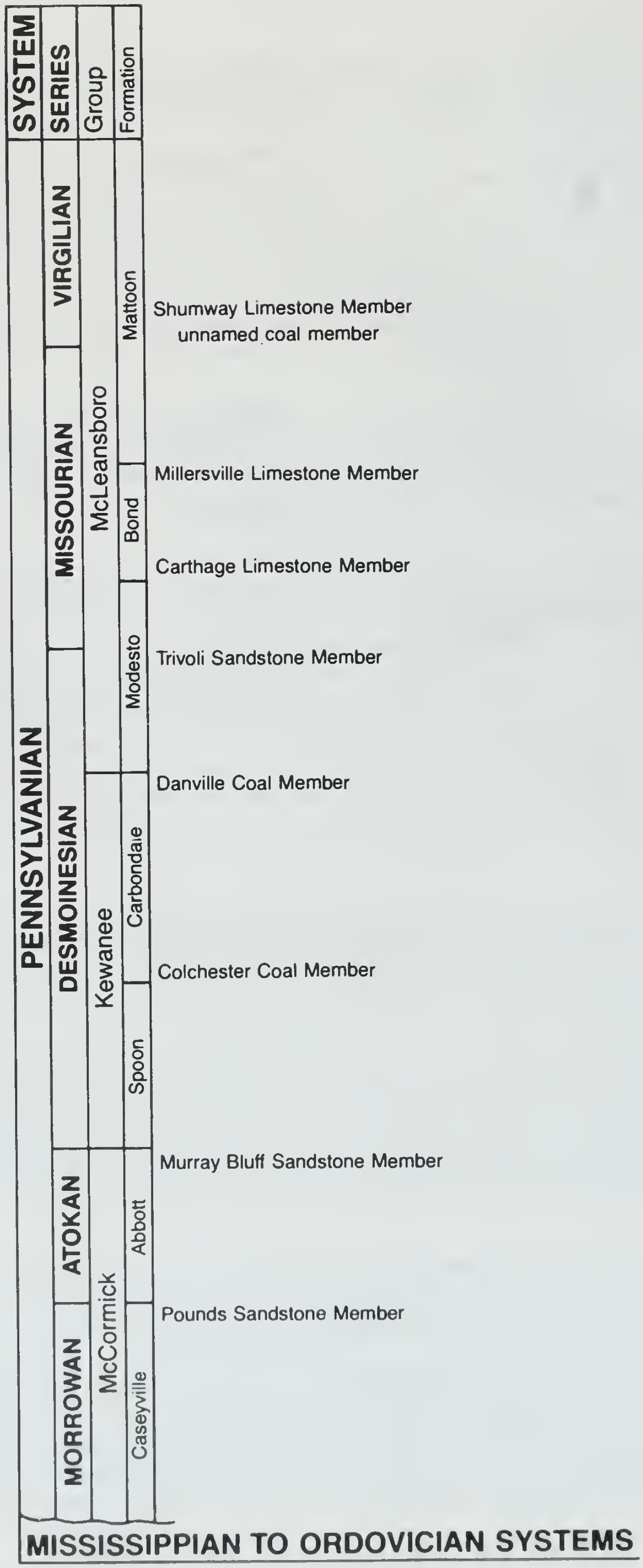
The periodic invasions of the Pennsylvanian sea across the coastal swamps killed the Pennsylvanian forests, and the peat deposits were often buried by marine sediments. After the marine transgressions, peat usually became saturated with sea water containing sulfates and other dissolved minerals. Even the marine sediments being deposited on the top of the drowned peat contained various minerals in solution, including sulfur, which further infiltrated the peat. As a result, the peat developed into a coal that is high in sulfur. However, in a number of areas, nonmarine muds, silts, and sands from the river system on the coastal plain covered the peat where flooding broke through levees or the river changed its coarse. Where these sediments (unit 6 of the cyclothem) are more than 20 feet thick, we find that the coal is low in sulfur, whereas coal found directly beneath marine rocks is high in sulfur. Although the seas did cover the areas where these nonmarine, fluvial sediments covered the peat, the peat was protected from sulfur infiltration by the shielding effect of these thick fluvial sediments.

Following burial, the peat deposits were gradually transformed into coal by slow physical and chemical changes in which pressure (compaction by the enormous weight of overlying sedimentary layers), heat (also due to deep burial), and time were the most important factors. Water and volatile substances (nitrogen, hydrogen, and oxygen) were slowly driven off during the coal-forming ("coalification") process, and the peat deposits were changed into coal.

Coals have been classified by ranks that are based on the degree of coalification. The commonly recognized coals, in order of increasing rank, are (1) brown coal or lignite, (2) sub-bituminous, (3) bituminous, (4) semibituminous, (5) semianthracite, and (6) anthracite. Each increase in rank is characterized by larger amounts of fixed carbon and smaller amounts of oxygen and other volatiles. Hardness of coal also increases with increasing rank. All Illinois coals are classified as bituminous.

Underclays occur beneath most of the coals in Illinois. Because underclays are generally unstratified (unlayered), are leached to a bleached appearance, and generally contain plant roots, many geologists consider that they represent the ancient soils on which the coal-forming plants grew.

The exact origin of the carbonaceous black shale that occurs above many coals is uncertain. Current thinking suggests that the black shale actually represents the deepest part of the marine transgression. Maximum transgression of the sea, coupled with upwelling of ocean water and accumulation of mud and animal remains on an anaerobic ocean floor, led to the deposition of black organic mud over vast areas stretching from Texas to Illinois. Deposition occurred in quiet-water areas where the very fine-grained iron-rich



Generalized stratigraphic column of the Pennsylvanian in Illinois (1 inch = approximately 250 feet)

mud and finely divided plant debris were washed in from the land. Most of the fossils found in black shale represent planktonic (floating) and nektonic (swimming) forms — not benthonic (bottom-dwelling) forms. The depauperate (dwarf) fossil forms sometimes found in black shale formerly were thought to have been forms that were stunted by toxic conditions in the sulfide-rich, oxygen-deficient water of the lagoons. However, study has shown that the "depauperate" fauna consists mostly of normal-size individuals of species that never grew any larger.

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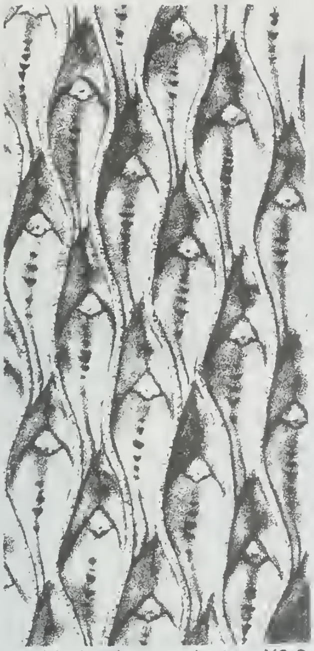
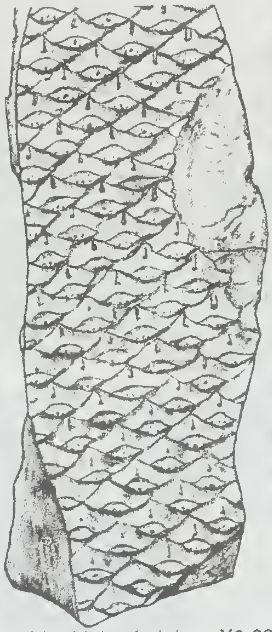
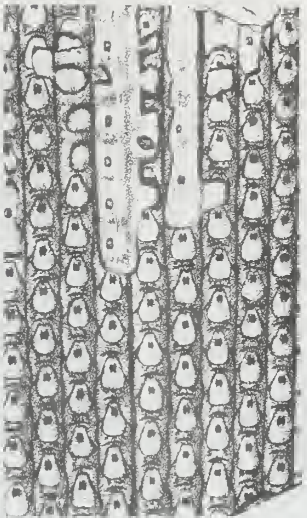
Common Pennsylvanian plants: lycopods, sphenophytes, and ferns



Lepidodendron aculeatum X0.8



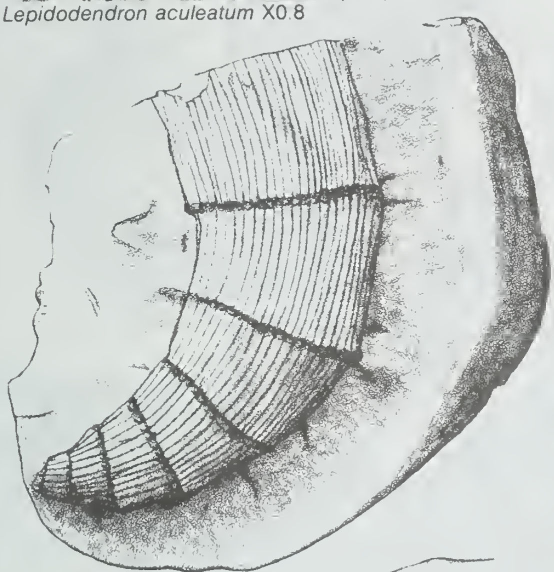
Lepidophloios laricinus X0.63



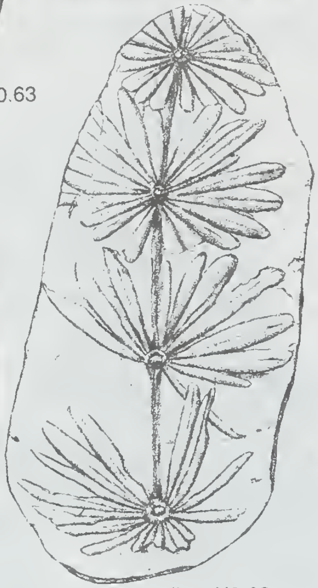
Sigillaria mammilaris X0.5

Stigmaria ficoides X0.32

Lepidostrobus ovatifolius X0.8



Calamites suckowii X0.5

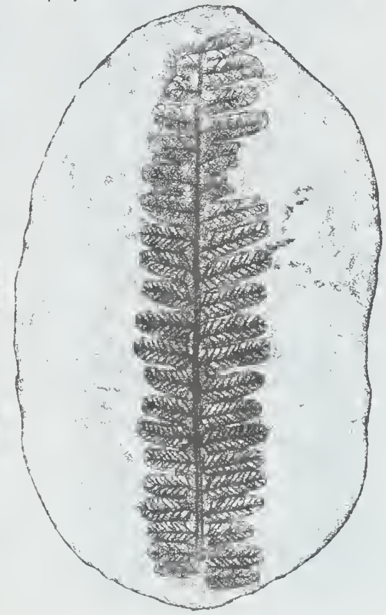


Annularia stellata X0.63

Sphenophyllum cuneifolium X0.4

Pecopteris sp. X0.32

Pecopteris miltonii X2.0

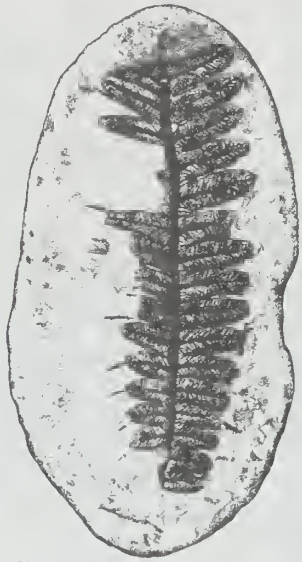


Pecopteris hemitelioides X1.0

J. R. Jennings, ISGS

Common Pennsylvanian plants: seed ferns and cordaiteans


Alethopteris serlii X0.63


Alethopteris ambigua X0.63


Neuropteris rarinervis X0.5


Mariopteris nervosa X0.8

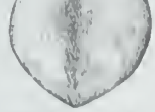

Neuropteris scheuchzeri X0.63


Sphenopteris rotundiloba X0.8


Trigonocarpus parkinsonii X1.25

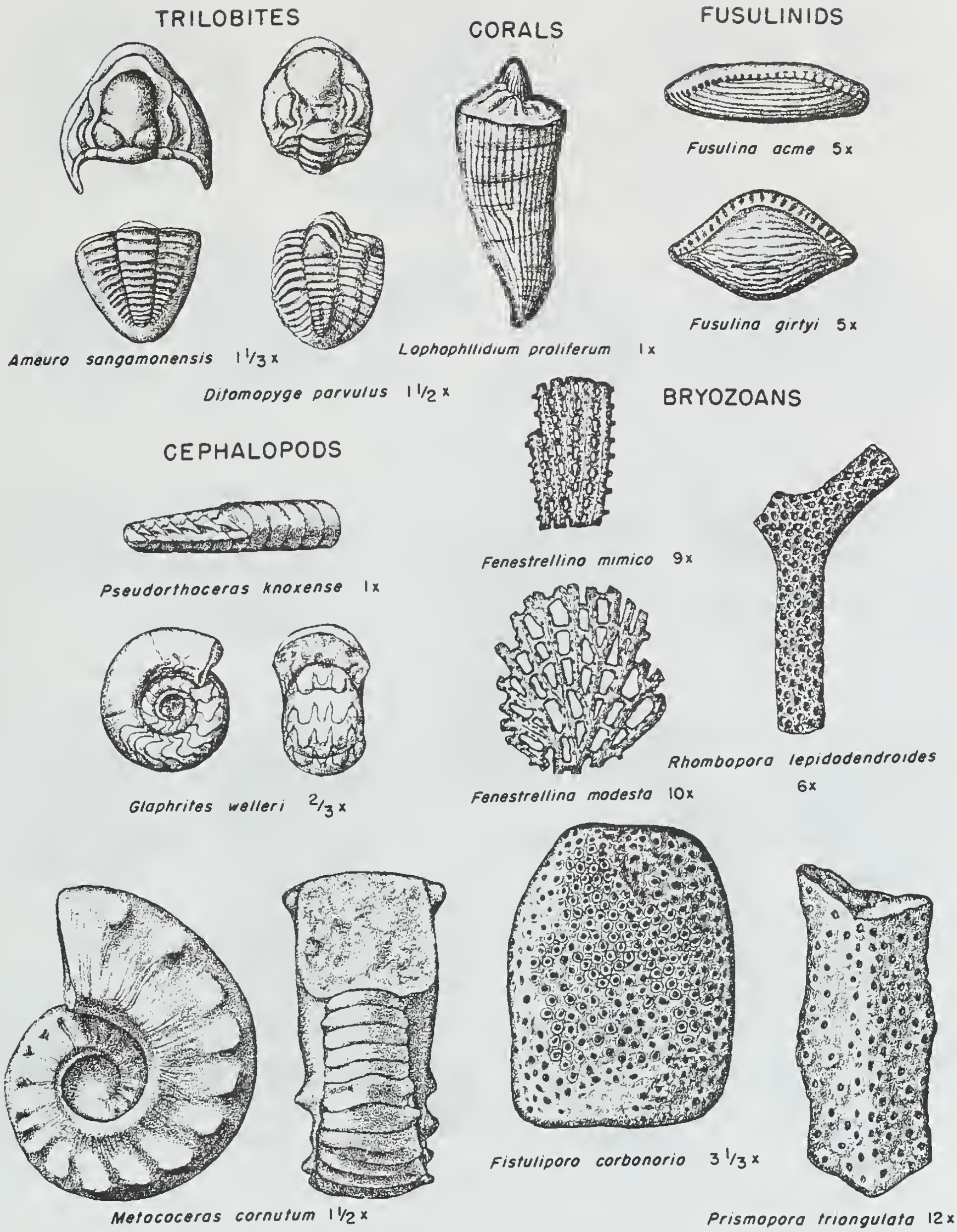

Cordaicladus sp. X1.0


Artisia transversa X0.63


Cordaicarpon major X2.0


Cordaites principalis X0.63

J. R. Jennings, ISGS


TRILOBITES
CORALS
FUSULINIDS
Fusulina acme 5x
Fusulina girtyi 5x
Ameura sangamonensis $1\frac{1}{3}$x
Lophophyllidium proliferum 1x
Ditomopyge parvulus $1\frac{1}{2}$x
BRYOZOANS
CEPHALOPODS
Pseudorthoceras knoxense 1x
Fenestrellina mimica 9x
Glaphrites welleri $\frac{2}{3}$x
Fenestrellina modesta 10x
Rhombopora lepidodendroides 6x
Fistulipora carbonaria $3\frac{1}{3}$x
Metacoceras cornutum $1\frac{1}{2}$x
Prismopora triangulata 12x

PELECYPODS

Nucula (Nuculopsis) girtyi 1x

Edmonia ovata 2x

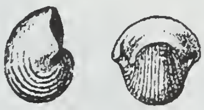
Astartella concentrica 1x

Dunbarella knighti 1 1/2 x

Cardiomorpha missouriensis "Type A" 1x

Cardiomorpha missouriensis "Type B" 1 1/2 x

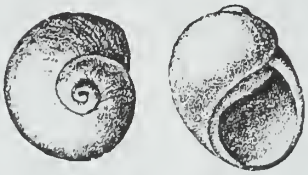
GASTROPODS



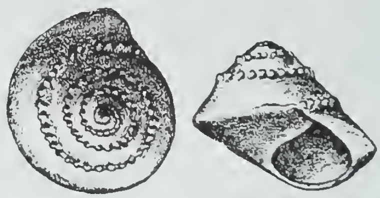
Euphemites carbonarius 1 1/2 x

Trepospira illinoisensis 1 1/2 x

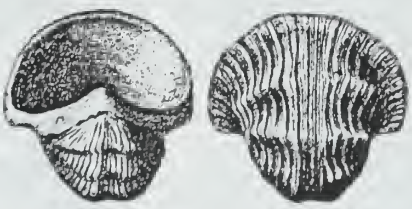
Donaldina robusta 8x



Naticopsis (Jedria) ventricosa 1 1/2 x



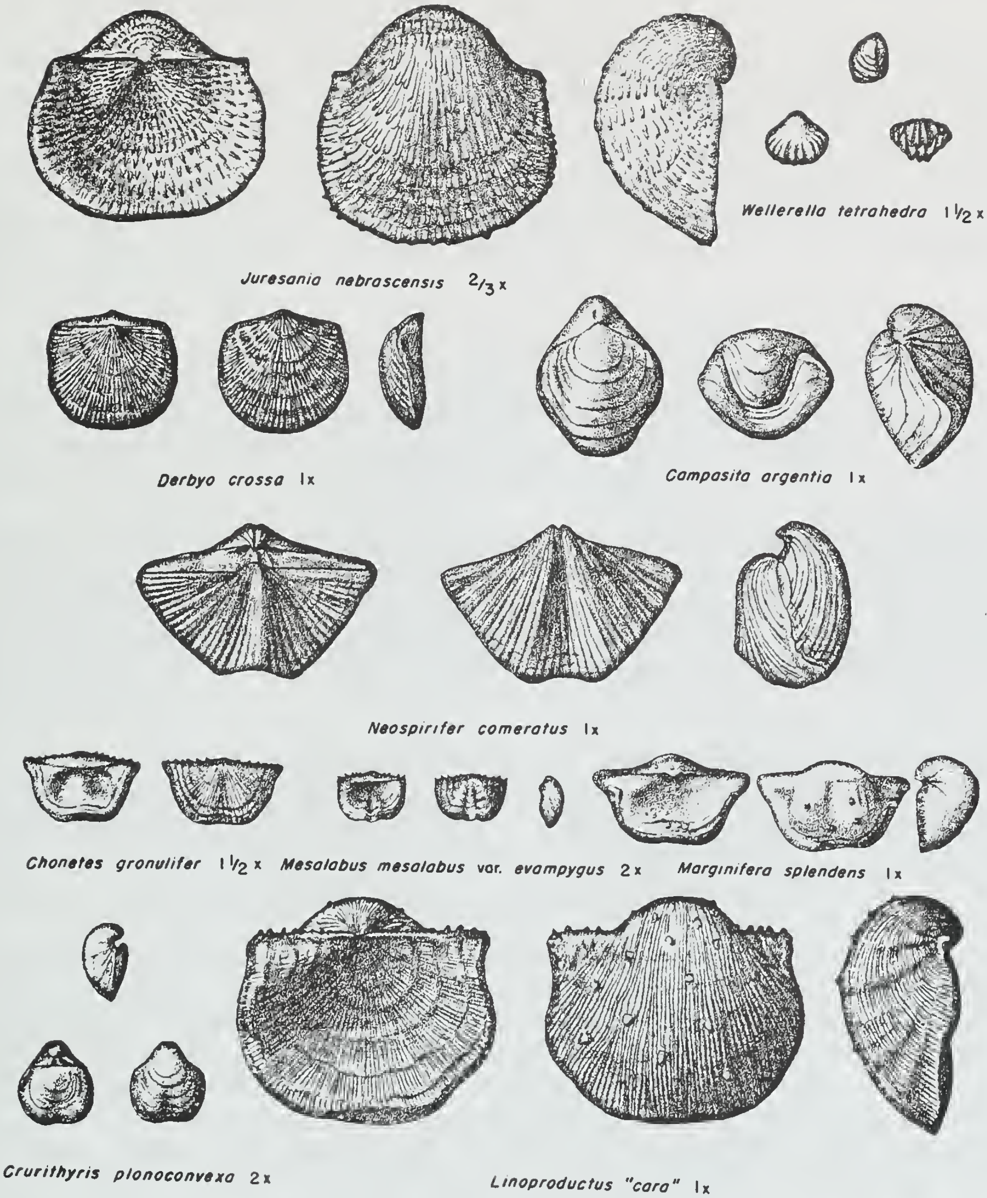
Trepospira sphaerulata 1x



Knightites montfortianus 2x

Glabrocingulum (Glabrocingulum) grayvillense 3x

BRACHIOPODS



DEPOSITIONAL HISTORY OF THE MISSISSIPPIAN ROCKS

During the Mississippian Period, from 350 to 310 million years ago, the midcontinent of North America was a generally low-lying, nearly level, and stable platform. Clear, warm, shallow seas invaded the region, and the area that is now the Mississippi Valley remained almost continually submerged throughout Mississippian time. During the middle the period, the sea reached far to the north, and little sand and mud was carried into the Illinois Basin.

The relatively pure lime muds of the Valmeyeran Series, including the Burlington, Keokuk, Fort Payne, Ullin, Salem, St. Louis, and Ste. Genevieve Limestones, were deposited over enormous areas on the continental platform. The sea in which these limestones were deposited was fairly shallow, probably only a few hundred feet deep generally, and in many areas only a few tens of feet. Imagine an area much like the Bahama banks or Florida Bay, north and west of the Florida Keys. Marine animals found such shallow seas ideal for their development. Some of the limestones are almost entirely cemented fossil fragments or oolites and thus reflect the shallow, wave-swept conditions of deposition.

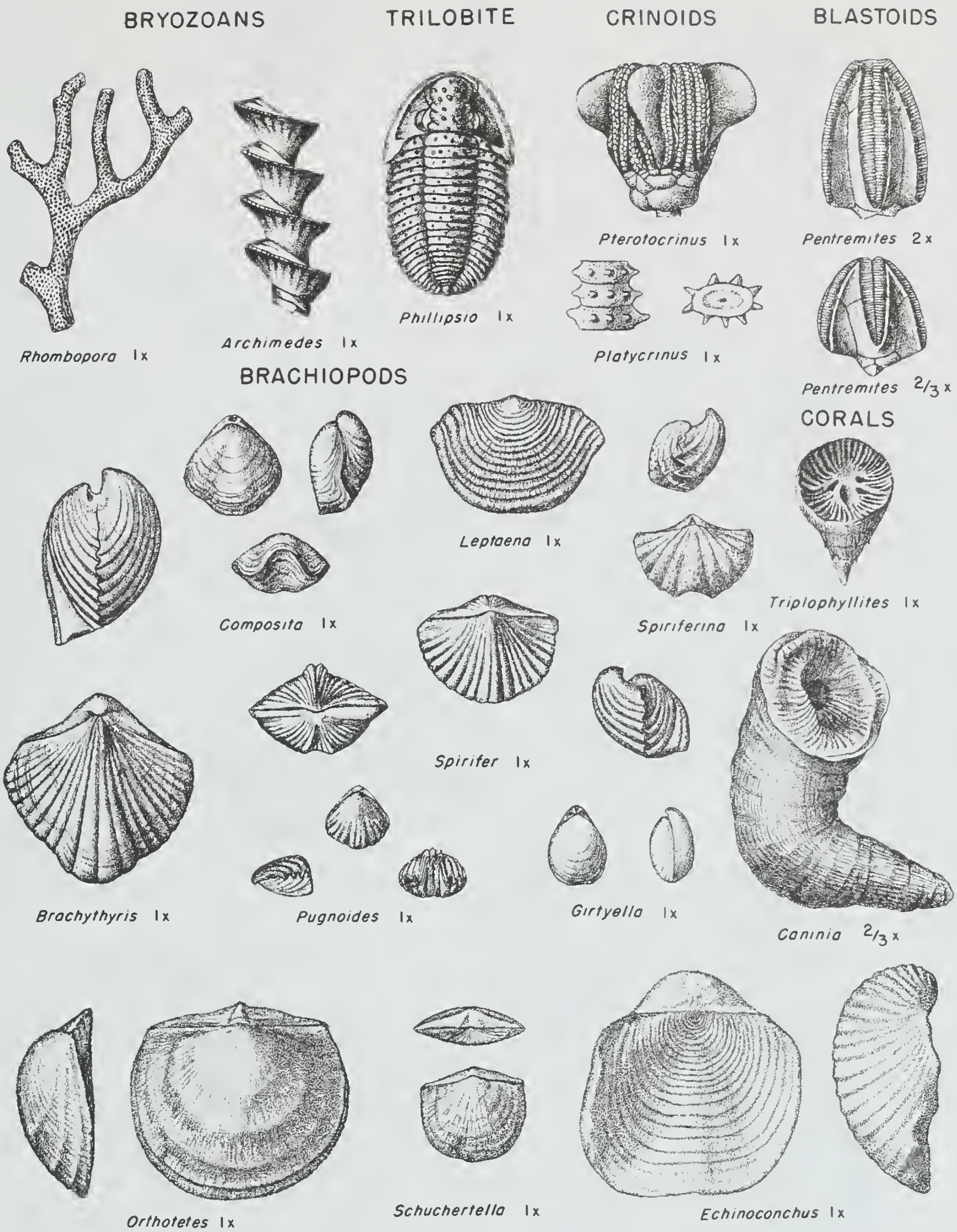
Throughout Mississippian time the Illinois Basin was a slowly subsiding (sinking) region, flanked on the east by the Cincinnati Arch and on the west by the Ozark Dome, both structurally high (positive) areas. These higher areas supplied little sand and mud to the Illinois Basin, and most clastic sediments were carried into the basin from land far to the north and northeast, in what is now Canada, by an ancient river system called the Michigan River.

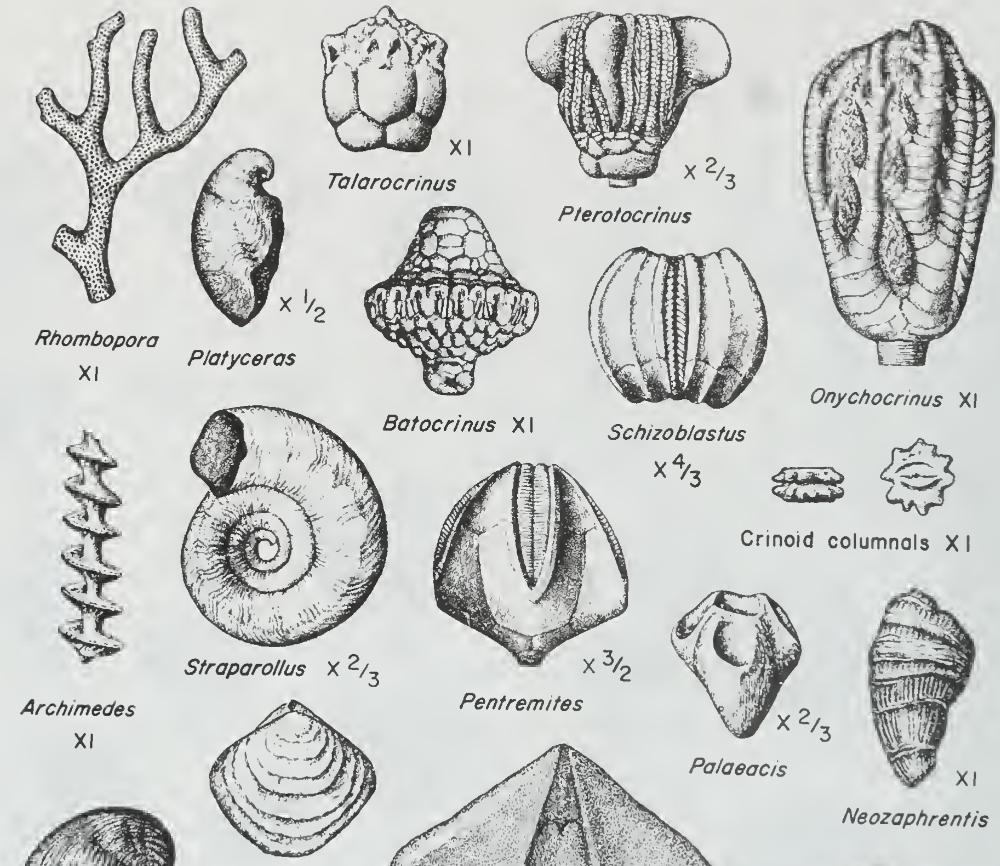
Near the end of Valmeyeran time the sea became more restricted in extent and the shoreline shifted southward. Increased amounts of sand and mud were delivered into the Illinois Basin by the Michigan River. Thin shales and sandstones in the upper part of the Ste. Genevieve Limestone indicate the depositional changes that were taking place. The overlying Aux Vases Sandstone records a great increase in the amount of sand deposited in the nearshore areas of the Mississippian sea.

During the latter part of the Mississippian Period much greater amounts of sand and mud were carried to the sea by the Michigan River. A great delta was built out into the sea. It was very much like the present Mississippi River delta in Louisiana. As the Illinois Basin subsided periodically and as the amounts of sand and mud carried into the sea fluctuated, the position of the shoreline and the edge of the delta oscillated northward and southward for hundreds of miles.

The fluctuating shoreline, the shifting position of the delta's distributary channels, and the continually changing water depths produced the striking vertical and lateral variations in the lithology that characterize the Chesterian Series. Regular alternations of sandstone, shale, and limestone formations were formed, each alternation beginning with deposition of basal sandstone and shale followed by deposition of limestone. Sandstones and shales record times when the delta front extended far out into the basin. Limestones indicate times when the shoreline was farther away and marine conditions prevailed. In some respects the alternations of the sediments of the Chesterian Series resemble the cyclothems of the Pennsylvanian System, which overlies the Mississippian rocks in much of Illinois (see attached geologic map).

Some Chesterian limestones are very pure, but others are quite argillaceous (clayey) and sandy. Generally, the Chesterian sea was very shallow. Cross-bedding and oolitic zones are common in the limestones, as are zones that consisting of a hash of fossil remains that were broken by wave action. Sedimentary features such as pebbly zones, ripple marks, and cross-bedding are present in the sandstones, many of which are distributary and river channel sands. Thin coal seams associated with some of the sandstones indicate times when the sea withdrew temporarily and plant debris accumulated in fresh-water swamps. These late Mississippian coal swamps were forerunners of those that occurred more extensively later, during Pennsylvanian time.


BRYOZOANS
TRILOBITE
CRINOIDS
BLASTOIDS
Rhombopora 1x
Archimedes 1x
Phillipsia 1x
Pterotocrinus 1x
Pentremites 2x
Platycrinus 1x
Pentremites 2/3 x
BRACHIOPODS
CORALS
Leptaena 1x
Composita 1x
Triplophyllites 1x
Spiriferina 1x
Spirifer 1x
Brachythyris 1x
Pugnoides 1x
Girtyella 1x
Caninia 2/3 x
Orthotetes 1x
Schuchertella 1x
Echinoconchus 1x


Rhombopora
X1
Platyceras
X 1/2
Talarocrinus
X1
Pterotocrinus
X 2/3
Onychocrinus X1
Batocrinus X1
Schizoblastus
X 4/3
Crinoid columnals X1
Archimedes
X1
Straparollus X 2/3
Pentremites
X 3/2
Palaeacis
X 2/3
Neozaphrentis
X1
Cleiothyridina
X1
Syringothyris
X 2/3
Spirifer
X 2/3
Skelidorygma
X 2/3
Ovatia X1
Endothyra X20
Lithostrotionella X1

START
LUNCH
END
1
2
3
4
5
6
7
8
Beardstown
Rushville
Ripley
Bluff Springs
Virginia
Arenzville
Meredosia
Versailles
Frederick
Browning
Chandlerville
Hagener
La Grange
La Grange Lock and Dam
Pleasant View
Shady Acres
Concord
SCHUYLER CO
CASS CO
MASON CO
BROWN CO
MORGAN CO
PIKE CO
ILLINOIS RIVER
SANGANOIS STATE CONSERVATION AREA
MEREDOSIA NATIONAL WILDLIFE REFUGE
BURLINGTON
NORTHERN
0 1 2 3 4 mi
0 2 4 6 km